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PROFESSOR MACLAGAN, M.D., Vice-President, in the Chair.

The following Communications were read:—

1. On a Specimen of *Balænoptera borealis* or *laticeps* captured in the Firth of Forth. By Professor Turner.

In September 1872 a whale of some magnitude was seen floundering in shallow water at Snab, Kinneil, about a mile from Bo'ness, on the Firth of Forth. Some men proceeded to the spot and fastening a rope round its tail, hauled it closer to the shore, and then killed it. I was not at home at the time, but on reading a notice of its capture in the *Scotsman* of September 26, I wrote to my assistant, the late Mr A. B. Stirling, to go and see the animal. He reported to me that it was a whalebone whale, ribbed and grooved on the belly, and he was able to make the following notes on its colour and dimensions:—

The animal was black on the back of the head and body and dorsum of the tail. The belly was pinkish white, with a shade of yellow, from chin to anus. Behind the anus it was patched with white to three feet from the tail. Behind this again the colour varied from lead grey to black, and the under as well as the upper surface of the tail was black. The breadth of the dorsum of the head at the tip of the upper lip was 2 inches; one foot further back it was 9 inches; two feet back 18 inches; and at the blowholes, 3 feet. The dorsal fin had a falcate posterior border, and its long diameter along the anterior border to the tip was 1 foot 8 inches, whilst its height was 11 inches. The flipper, when disarticulated at the shoulder, was 4 feet 10 inches in length. The breadth of the tail was 8 feet 8 inches: its anterior border was convex, its posterior border festooned. From the root of the tail to the mesial notch was 2 feet 5 inches, and the depth of the notch was 5 inches. The lower jaw projected both in front of and to the sides of the upper jaw. The length of the animal, from the tip of the beak to the end of the tail, was about 37 feet, and the girth round the belly about 15 feet.

The whale was taken possession of by the Custom House officials, and was then sold by public auction.

When I saw it a few days afterwards the blubber and baleen had been removed from the animal. The baleen consisted of numerous plates, the biggest of which were about 1 foot 3 inches in length and about 6 inches wide. They were black, striped with grey and white, and the hairs projecting from the lower free border were greyish-white.

The fluted state of the belly and the presence of a dorsal fin proved it to be one of the Balænopteridæ, or Finner whales. It was evident, both from the colour of the whalebone and the shape of the upper jaw, the lateral borders of which were straight, that the animal was not the *Balænoptera sibbaldii*, a magnificent example of which had been stranded at Longniddry only three years before.* Its size and the colour of its baleen distinguished it also from the lesser piked whale, *Balænoptera rostrata.* The absence of yellowish and greenish tints in the plates of the whalebone threw some doubt on its being *Balænoptera musculus*, but I was not in a position, in the condition the animal then was, to discriminate between *Balænoptera musculus* and *B. borealis.* I decided, therefore, to buy the carcass, and to have the skeleton prepared for the Anatomical Museum of the University. Accordingly men were engaged to take the flesh off the bones, and to separate it into pieces of convenient size for transport into Edinburgh. I regret to say that the sternum and pelvic bones were lost amidst the masses of flesh, and could not be recovered; but with these exceptions, and that of a carpal bone, some of the smallest phalanges, and perhaps one or two chevrons, the skeleton is, I believe, perfect. As the bones of the large cetacea are, from the quantity of oil which they contain, difficult to clean, I obtained permission from my colleague, Professor Balfour, to bury them in the Botanic Gardens in a mixture of leaves and earth. They remained there until the summer of last year, when they were disinterred, clean and free from grease and smell. The examination which I have subsequently made of the skeleton has satisfied me that the animal was the cetacean named by zoologists *Balænoptera borealis* or *laticeps.*

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* See my account of this animal in *Trans. Roy. Soc. Edin.*, 1870, vol. xxvi.

The only specimen captured in the British seas, which has been referred to this species by some zoologists, is one stranded at Charmouth, Dorsetshire, in 1840. From the colour of its baleen and the number of its vertebræ (60), it was much more likely to have been *Balænoptera musculus.* But as the skeleton has not been preserved, its identification is now rendered difficult. As no properly authenticated specimen of *B. borealis* had therefore previously been captured in the seas of our islands, I have the satisfaction of adding this mammal to the British Fauna.

In the Museum of the Royal College of Surgeons of England are some vertebræ and other bones of this species, but nothing is known of their history. In the University Museum, Cambridge, are the skull and one scapula of a whale cast ashore on the island of Islay, in 1866, which Professor Van Beneden referred at one time to this species.* Mr. J. W. Clark has, however, pointed out† that it is the skull of a very fine *Balænoptera rostrata,* and Professor Flower tells me that he is of the same opinion. Skeletons of *B. borealis* are preserved in the Museums at Leyden, Berlin, Bergen, Brussels, and Bayonne. The Leyden specimen was taken in 1811, near to Moniken Dam, in the Zuider Zee, and the characters of the skeleton have been given by Professor Flower.‡ The Berlin specimen, figured and described by Rudolphi,§ was taken in 1819 on the coast of Holstein, near to Gromitz. Two skeletons are at Bergen, the one was described by Lilljeborg,‖ from a young animal captured on the Norwegian coast; the other came from the Loffoden Islands,¶ and has apparently not yet been described. The Brussels skeleton was obtained by Eschricht from the North Cape, and has been described by Van Beneden.* The skeleton in the Museum at Bayonne is a young male specimen, which M. P. Fischer states was stranded near Biarritz in July 1874.† The animal was 7·83 mètres long (about 26 feet). *B. borealis* is therefore a denizen of the North Atlantic Ocean.‡

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* *Ostéographie des Cétacés,* p. 202.

† See reference in *The Fauna of Scotland,* "Mammalia," by E. R. Alston, Glasgow, 1870. Also, in a letter to myself, in reply to a communication on the subject.

‡ *Proc. Zool. Soc. London,* Nov. 8, 1864.

§ Rudolphi named this animal *Balæna rostrata. Abhand. der Akad. der Wissensch. zu Berlin,* 1820, 1821.

‖ Translation of Lilljeborg's *Memoir on the Scandinavian Cetacea,* in publications of Ray Society.

¶ *Ostéographie des Cétacés,* p. 201.

It is not my intention on this occasion to enter in detail into the description of the skeleton of this whale stranded near Bo'ness, but it will be necessary to refer to such points in its anatomy as will give certainty to the identification of the species. The bones of this animal were less massive, smoother on their surface, and less porous than the bones of either *B. musculus* or *B. sibbaldii*. The vertebral plates were not anchylosed to their respective bodies, and the epiphyses of the radius, ulna, and humerus were not united to the shafts of their respective bones.

The entire length of the skull and spine was 35 feet 2¼ inches, viz., the skull, 8 feet 1¼ inches; the spine, without the intervertebral discs, 26 feet 7 inches. If to this be added 2 feet for the probable thickness of the intervertebral discs, and 8 or 10 inches for the projection of the lower jaw beyond the upper and the thickness of the skin, the length of the animal would have been about 38 feet, which closely approximates with what was reported as its length before being flensed. Although the condition of the epiphyses proved that the animal had not reached adult life, or probably attained its full dimensions, yet this skeleton is larger and more advanced in its ossification than the other skeletons which have been described. The Leyden specimen is said to have been 32 feet long, and Professor Flower gives its skeleton as 29 feet 7 inches, without the intervertebral discs, for the thickness of which an additional 2 feet should be allowed. Professor Rudolphi states that the Berlin skeleton is 31 feet 1 inch Rhenish measurement. The young skeleton in Bergen described by Lilljeborg is 30 feet 2 inches; and Professor Van Beneden names 32 feet as the length of the specimen in the Brussels Museum. From these measurements, M. Van Beneden concludes that this species of whale does not appear to exceed 35 feet in length. But the dimensions of the specimen now before us, which is obviously not an adult, would lead one to say that this animal may attain a length of 40 feet, or even more. Whilst larger than *B. rostrata*, it is considerably smaller than *B. musculus*, and still more than *B. sibbaldii.*

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* *Ostéographie des Cétacés*, p. 302.

† *Comptes Rendus*, 27th Dec. 1876, p. 1298, vol. lxxxiii.; and *Journal de Zoologie*, vol. v. p. 462, 1876.

‡ In *Nature*, 12th Oct. 1876, is a reference to the *Schriften der naturforschenden Gesellschaft in Dantzig*, which contains photographs of the skeleton of a whale, said to be *Pterobalæna laticeps* (Gray), stranded in Dantzig Bay in 1874, but as I have not been able to obtain a copy of the Dantzig publication, can make no further reference to it. I observe that in the *Archiv für Naturgeschichte*, 1875, 41st year, third part, p. 338, is an elaborate description, by Professor Zaddach of Königsberg, of a female fin whale, stranded in August 1874, between Neufahrwasser, the harbour of Dantzig, and the village of Heubude. He names it *Balænoptera musculus*. Its vertebral formula is $C_7D_{14}L_{15}Cd_{24} = 60$, and the baleen is described as yellow like horn, with bluish-green or blackish spots at the outer border. Its length was 10·98 mètres (about 36 feet English). Professor Zaddach states that he does not give a detailed description of the skeleton, as the Dantzig Society of Natural History had decided to publish a description of it, with drawings and photographs, in their *Schriften*, from the pen of Professor Menge. Can this be the specimen referred to in *Nature*? The colour of the baleen and the vertebral formula (probably the last two caudals had not been ossified and preserved) show its affinity to *B. musculus* rather than to *B. laticeps*.

Spine.—The vertebræ numbered in this specimen fifty-six; and as the last caudal was only 1½ inch in its transverse and 1¼ in its antero-posterior diameter, it is probable that all the vertebræ were secured. The formula was as follows:—$C_7D_{14}L_{14}Cd_{21} = 56$. In the Leyden specimen there were also fifty-six vertebræ, the two last caudals being fused together, viz., C_7D_{13} or $_{14}$, L_{16} or $_{15}$, Cd_{20}. Rudolphi states that the Berlin skeleton had fifty-four vertebræ, though Eschricht says fifty-five, and one was probably missing. Lilljeborg states that the young skeleton in Bergen had fifty-five vertebræ, viz., $C_7D_{13}L_{14}Cd_{21}$. In the Brussels specimen the terminal caudals were lost, but the vertebræ present were $C_7D_{14}L_{15}$, and fifteen caudals. The Bayonne skeleton had only fifty-four vertebræ, but the animal was young, and the two terminal caudals were probably not ossified. Fifty-six is probably, therefore, the normal number of vertebræ, and of these fourteen are dorsal, so that there are fourteen pairs of ribs, which is the number present in my specimen. The vertebral formula, therefore at once distinguishes *B. borealis* from the other species of the genus; for in *B. rostrata* the formula is $C_7D_{11}L_{13}Cd_{17} = 48$, and there are only eleven pairs of ribs. In *B. musculus* the formula is $C_7D_{15}L_{15}Cd_{25} = 62$, and there are, as a rule, fifteen pairs of ribs. In *B. sibbaldii* the vertebræ are sixtythree or sixty-four, and the formula is C_7D_{15} or $_{16}$, $L_{15}Cd_{26}$, and there are fifteen or sixteen pairs of ribs. *Balænoptera borealis* is, therefore, intermediate in length, in the number of its vertebræ and of its ribs to *B. rostrata* on the one hand, and to *B. musculus* and *B. sibbaldii* on the other.

The seven cervical vertebræ of my specimen are all separate bones, except that the right lateral mass of the atlas is anchylosed to the body of the axis. This is an exceptional arrangement in the fin whales, and has not apparently been seen in any of the other skeletons of *borealis*. The atlas has a transverse process, short, twisted, and compressed from before backwards, and a median backward-projecting ventral process corresponding with Professor Flower's description of the Leyden specimen. The ring is markedly divided into an inferior part for the rudimentary odontoid, and a superior rachidian part by a process projecting inwards on each side. This character is also well seen in the atlas in the Museum of the College of Surgeons, London. The height of the atlas is 10½ inches; that of the axis 13 inches. The extreme transverse diameter of the atlas is 14½ inches; that of the axis 21¾ inches. The axis has a thick spine. The transverse process has a slender upper and a plate-like lower limb, which unite externally to form a broad plate-like process directed backwards and outwards. The vertebrarterial foramen is only 1¾ by 2½ inches, and is placed near the upper border of the process. The rachidian ring is 4¼ by 3½ inches. In the 3rd and 4th vertebræ the vertebrarterial foramen is completed by the junction externally of the superior and inferior limbs of the transverse process. In the 5th vertebra these processes are separated externally by an interval of ½ inch; in the 6th, by an interval of 1½ inch; in the 7th, whilst the superior limb is long and curved downwards and outwards, the inferior limb is represented by a mere tubercle. In the Leyden specimen the vertebrarterial foramen is incompletely bounded in the 2nd to the 7th inclusive. In the Berlin and Bergen skeletons only the axis has the foramen completely bounded by bone. In the Brussels skeleton only the axis and 3rd vertebræ. The ossification is therefore more advanced in this region in my specimen than in these other skeletons.

The flat surfaces of the upper transverse processes are almost vertical; those of the lower transverse process of the 6th cervical are almost horizontal. From the root of the lower transverse process of the 4th, 5th, and 6th a stout conical process projects forwards.

The dorsal vertebræ increased in magnitude from before backwards. The 1st had a vertical diameter to the summit of the spine of 13½ inches, and a transverse, between the tips of the transverse processes, of 19½ inches. The last dorsal had a vertical diameter of 22¾ inches, and a transverse of 30 inches. All the dorsal vertebræ were marked by an articular surface for a rib at the free end of the transverse process. They were not keeled on the ventral surface of the body.

The lumbar vertebræ were, as a rule, somewhat bigger than the hinder dorsal, and reached their maximum at the 8th, 9th, and 10th. The 9th lumbar had a vertical diameter of 24½ inches, and a transverse of 31 inches. Behind the 10th the transverse and spinous processes gradually diminished in their amount of projection as they passed back into the caudal region, and in the 12th vertebra from the end of the tail the transverse process was represented by a faint ridge on the side of the body, and the spine was rudimentary. In the 9th vertebra from the end of the tail the spine and laminæ had disappeared, and the neural canal was represented by a groove, which was faintly seen on the two vertebræ next behind, and then disappeared. In the 12th vertebra from the end of the tail a foramen, directed vertically, was situated at the root of the rudimentary transverse process, and a similar foramen was found in the caudals up to and including the 18th from the end of the tail. This arrangement closely resembles that figured by Rudolphi in the Berlin skeleton. The lumbars were all keeled on the ventral surface of the body, though, as a rule, the keel was slight in relation to the size of the bone.

Eleven chevron bones were present. The articulations for the chevron bones began on the 15th vertebra of the lumbo-caudal series (counting from the front) in a pair of surfaces situated at the posterior border of the ventral surface of the body of that vertebra; and distinct articulations for these bones could be seen as far back as the 27th lumbo-caudal vertebra. Hence I have regarded all the vertebræ behind the 14th lumbar as caudal vertebræ. In the 1st caudal the ventral keel was very slight, and a shallow groove was seen posteriorly between the articulations for the 1st chevron bone.

The caudals behind the first were all grooved on the ventral surface, and the groove in many instances possessed considerable depth. The spines of some of the lumbar and the more anterior caudals had sharp bony outgrowths projecting from the posterior border.

Ribs.—There were fourteen pairs of ribs. The 1st was flattened, and measured in a straight line 25¼ inches on the left side and 25 inches on the right; the breadth of the sternal end of the 1st left was 4¾ inches. The 2nd rib was 37¾ inches long on the left side and 33¼ inches on the right side. The ribs increased in length, as far back as the 6th rib, which measured 4 feet 3 inches in a straight line; from the 7th to the 14th they diminished in size, and the last rib was 2 feet 3 inches in length; they were slender rod-like bones. All the left ribs were separate bones, but the right 1st rib was fused with the 2nd at the sternal end, where they formed a plate of bone 13¾ inches broad. The breadth was partly due to a broadening of the sternal end of the 2nd rib, and partly to the formation of bone in the 1st intercostal space, for a distance of 6 inches from the sternal end, which was fused with the borders of both the 1st and 2nd ribs, and, together with them, formed the broad plate above referred to. On the 3rd and 4th ribs well-marked capitular processes extended from the vertebral articular surface towards the body of the vertebra. Rudimentary capitular processes were present on the 2nd and 5th, but were absent on all the other ribs.

In all the skeletons of *B. borealis* which have previously been described, the 1st rib had the peculiarity of possessing two heads. In the Leyden specimen the cleft which separated these heads from each other had a depth of 5 inches (Flower). From the figure given by Rudolphi of this rib in the Berlin skeleton, it is probable that the cleft had a similar depth. In Lilljeborg's Bergen skeleton the 1st pair are considerably wider than the others, with the upper end forked or "biceps," and the lower rather dilated and much wider than the upper. In the Brussels skeleton, as figured by Van Beneden, one of the first ribs has the same character, and in the Museum of the Royal College of Surgeons of England are the first ribs of two individuals of this species, which are also bicipital. M. Fischer does not describe the skeleton of the Bayonne specimen, but notes that the spinal end of the 1st rib is bicipital. M. Van Beneden had the advantage of seeing the ribs in place before the flesh was removed. He states that on the right side an elongated, compressed movable bone, curved like a rib, was applied to and articulated with the anterior surface of the 1st true rib, and on the left side a similar rudimentary rib was present, which was fused with the body of the first true rib, so as to give it a bicipital appearance. Both Professors Flower and Van Beneden regard this supplementary part of the 1st rib as a cervical rib, so that the double vertebral end of this rib articulates with both the 7th cervical and 1st dorsal vertebræ. In my skeleton no supplementary cervical rib was present. The two ribs which were fused together on the right side, at the sternal end, were the 1st and 2nd thoracic ribs, and differed therefore from the condition described in the other skeletons. The constancy with which the bicipital form of the 1st rib had been seen, in the skeletons of this animal previously described, had given rise to the impression that it might almost be regarded as a specific character, and the late Dr. J. E. Gray even went so far as to give it generic importance, and named Rudolphi's whale *Rudolphius laticeps.*[1] In a criticism which I made some years ago on the value of this character for purposes of classification,[2] I argued that the presence of a cervical rib, whether blended or not with the 1st thoracic rib, was only an individual variation, and, as cervical ribs occasionally occur in men as well as in whales, that one should as little think of classifying men who possess cervical ribs as distinct from those who do not possess them, as found a genus of whales on the presence of these bones. The absence of a cervical rib in the skeleton now described, which is an undoubted specimen of *B. borealis* or *laticeps*, shows that the bicipital form of the 1st rib is not constant in this species; but as the majority of the skeletons which have been examined have two heads to this rib, its bicipital character would seem in this animal to be the rule, and not, as in man, the exception.

Skull.—The skull resembled, both in its general configuration and in detail, the figures of the skulls of this animal published by Rudolphi and Van Beneden. The sides of the beak were straight;

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[1] *Catalogue of Seals and Whales, and Supplement.*

[2] The so-called two-headed ribs in Whales and in Man, *Jour. of Anat. and Phys.* vol. v.

the premaxillaries projected 6 inches beyond the superior maxillaries. The upper surface of each nasal bone was 8¼ inches long, flattened in the posterior third, but slightly concave in the anterior two-thirds, owing to the inner border of that part of the bone being raised into a low longitudinal ridge. The anterior borders of the two bones were truncated, and formed together almost a straight line. The breadth of each bone at its posterior end was 1 inch, and at its anterior end 2½ inches. The premaxilla passed back as a thin plate between the nasal and superior maxilla, as far as the posterior end of the nasal. The superior maxilla passed back for 3 inches beyond the posterior end of the nasal.

The orbital border of the frontal bone was 14 inches in length; the antero-posterior diameter of the inner part of this bone was 16 inches. The anterior borders of this bone sloped outwards and slightly backwards, whilst the posterior border was almost transverse.

The anterior border of the occipital bone was 10½ inches wide, and almost transverse; the posterior border was 31¾ inches, and presented on each side from the foramen magnum outwards two concavities separated by an intermediate convexity.

The malar was 12 inches long, inclusive of the thin plate between the lachrymal and superior maxilla; the part which formed the proper lower boundary of the orbit was 8 inches. The lachrymal, 8½ inches long, was a thin plate of bone except at the anterior end, which was tuberculated.

The beak arched in the antero-posterior direction from base to tip, and the highest point of this arch was 5 inches above the chord of the arc.

The mandible was not strongly curved. The length of the lower jaw in a straight line was 8 feet 5¼ inches; and along the outer convex surface 8 feet 8 inches. The superior border was 11 inches at its farthest point from the chord of the arc. The coronoid process was low and triangular, its base was 8½ inches long, and its height from the base line was 3½ inches. The depth of the mandible, including the coronoid process, was 11¾ inches.

The hyoid closely resembles Rudolphi's figure, and, as it has not hitherto been properly described, and is so characteristic of this species, I shall give an account of it. The inferior surface of the middle of the body was slightly concave from side to side, and slightly convex from before backwards. The posterior border of the body was convex, and projected backwards considerably behind a line drawn across between the posterior border of the two great cornua. In this character it differed very markedly from both *B. sibbaldii* and *B. musculus.* The great cornu was flattened on its upper and slightly convex on its under surface, with the anterior border a little more rounded than the posterior; its antero-posterior diameter was almost uniform until near the tip. In *B. sibbaldii,* again, the great cornu swelled out so as to assume a remarkable fusiform shape, and to a less degree this is also seen in *B. musculus,* The stylo-hyals were flattened on both surfaces and 13½ inches long. The hyoid measured between the tips of the great cornua 21 inches.

The following table gives, in feet and inches, the principal dimensions of the skull:—

	FT.	IN.
From anterior border of foramen magnum over vertex to tip of beak, ...	8	9¼
From nasal end of superior maxilla to tip of beak, . .	6	9
From anterior border of foramen magnum to nasal end of superior maxilla, ...	2	0½
Breadth across posterior ends of superior maxillæ, . .	0	8¾
Greatest breadth of skull, ...	3	10¼
Breadth of skull at base of beak, ...	2	6
Breadth of skull at middle of beak, ...	1	5½
Breadth of skull between middle of orbital borders of frontals, ...	3	7½
Length of skull in a straight line (condylo-premaxillary), .	8	7¼
Length of beak, ...	5	9
Length of superior maxilla, ...	6	3
Length of premaxilla, ...	6	6½
Greatest breadth of superior maxilla behind base of beak, .	3	7
Greatest breadth between outer borders of both premaxillæ,	0	10
Greatest breadth of space between both premaxillæ, .	0	8
From foramen magnum to upper border of occiput, .	2	0

I have compared the tympanic bones with those of *B. rostrata*—the smallest—and *B. sibbaldii*—the largest—of the fin whales. Their dimensions expressed in inches were as follows:—

	Immature. *B. rostrata.*	Adolescent. *B. borealis.*	Immature. *B. Sibbaldii.*	Adolescent. *B. Sibbaldii.*
Length, .	3·5	4·8	4·7	5·3
Breadth, .	1·8	2·2	2·5	2·6

In *B. rostrata* the breadth index was 51, in *borealis* 46. The greater relative breadth of *rostrata* was due to both the outer and inner surfaces being generally more convex; but the anterior part of the outer surface of *rostrata* possessed a concave area more distinctly marked than in *borealis.* In *rostrata* the superior border between the two attachments of the petrosal was more horizontal than in *borealis,* and in the same specimen the posterior attachment of the petrosal was nearer the hinder end of the bone, which was more rounded in *rostrata* than in *borealis.* In *rostrata* the entrance to the tympanic cavity was relatively wider, with the rounded border relatively thicker; whilst the inferior border was less distinctly keeled than in *borealis.* In the adolescent *B. sibbaldii* the tympanic was broader in relation to the length than in *borealis,* and this greater relative breadth was still more strongly marked in the immature *sibbaldii,* the breadth indices in the two specimens being respectively 49 and 53. The greater breadth of *sibbaldii* was especially seen in the posterior third of the bone, which bulged considerably on the inner surface in *sibbaldii,* and was almost flat in *borealis.* This bulging caused a broadish concave surface at the root of the posterior attachment of the petrous bone in *sibbaldii,* whilst the corresponding area in *borealis* was a narrow groove. In *sibbaldii* the entrance to the tympanic hollow was more sinuous, and the rounded border of the bone much thicker than in *borealis.* In *sibbaldii* the anterior and posterior ends were less attenuated than in *borealis.* Through these characters there was no difficulty in distinguishing between the tympanics of these species, and the character which most impressed me in making this comparison was the relative want of breadth of *borealis.* I have not a tympanic bone of *B. musculus* at hand with which to compare my specimen, but from my recollection of a specimen I saw in the Royal Museum, Brussels, in May of last year, I should say that in *musculus* the tympanic had a greater breadth than in *borealis.*

Pectoral Limb.—The scapula was a triangular plate, measuring 29 inches between its superior and inferior angles, and 17½ inches in its glenoido-vertebral diameter. The coracoid was ¾ inch long, and 2¼ in its greatest breadth. The acromion was 6¾ inches long, and 4 in its greatest breadth. The humerus was only 11 inches long, and 1 foot 2¼ inches in circumference at the middle of the shaft, the surfaces of which were somewhat flattened. The ulna was 11 inches long, 5¾ broad at the upper end, measured across the olecranon, 3¼ at the lower end, and only 2¼ in breadth in the middle of the shaft. The radius was 20½ inches in length, and with much less difference in breadth between the upper and lower ends and the middle of the shaft than was seen in the ulna.

Thirteen carpal bones were present, and one was probably missing. Five pairs of these bones were nodular, in part tuberculated on the surface, and in part with flattened articular-looking surfaces, well marked in four pairs, very imperfect in one pair. One pair and the single bone were flattened, elongated, and uniformly tuberculated, without any appearance of an articular surface.

Thirty-three finger bones were present, and some of the smaller phalanges were either unossified or probably missing.

The comparison which I have so far made of the Bo'ness whale with other specimens has been with skeletons admittedly those of *B. borealis*, and obtained in the North Atlantic. But in the Leyden Museum is a skeleton brought from the north-west coast of Java, named, after Professor Schlegel, *Balænoptera Schlegelii*, which Professor Flower, who first described it, regarded as closely allied to, if not specifically identical with, *B. borealis*, though, on account of its *habitat*, he had a difficulty in placing it with *borealis.*[1] This skeleton was more perfectly ossified than in my specimen, and belonged to an animal probably about 45 feet long. I have compared my skeleton with Professor Flower's description and figures, and with the additional description and illustrations of its skeleton in Pls. XIV. and XV., and on p. 221 of the *Ostéographie des Cétacés*, and without doubt the resemblance is in many particulars very striking.

The mandible with its low coronoid process, the profile outline of the skull, the flattened stylo-hyals, the general form of the tympanic, the cervical vertebræ, the general form of the dorsals and lumbars (the latter with their spiculated spines), the scapula, the humerus, radius, and ulna, all closely corresponded. The Java specimen possessed also fourteen pairs of ribs and fifty-four vertebræ, $C_7 D_{14} L_{14} Cd_{19}$. Professor Flower thinks that three or four caudals are wanting, but Professor Van Beneden considers only one or two are missing.

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[1] *Proc. Zool. Soc.*, London, Nov. 8, 1864.

On the other hand, the nasal bones are obviously flatter and longer; the antero-posterior diameter of the orbital border of the frontal is relatively not so long; the double curve of the posterior border of the occipital is not so marked, and its base is wider (Van Beneden) in *Schlegelii* than in *borealis*. Again, my specimen does not have a pair of strong tubercles projecting from the posterior border of the body of the hyoid, as in the Java specimen, and the first rib is not bicipital.

Some of these differences may be due to the more advanced ossification of the Java skeleton, and the longer and stronger spines of the dorsal and lumbar vertebræ, which M. Van Beneden refers to, are obviously due to the same cause. The greater length of the Java skeleton has not the importance which Van Beneden attaches to it, as I have already maintained that *borealis* may attain a length of 40 feet or upwards, and the ribs in the Java specimen corresponded in number with those in my skeleton.

At the time when Professor Flower wrote his description, there was a greater tendency, on the part of cetologists, to limit the area of distribution of the individual species of cetacea, than now exists, and to confer specific value upon specimens which, though in many respects similar in characters, yet came from distant seas. The wider range of distribution of some of the species of the marine mammals is now more generally recognised, and the remoteness of the *habitat* of Schlegel's *Balænoptera* ought not, if the anatomical arrangements correspond, to bar its association with *B. borealis*.

2. On Minding's Theorem. By G. Plarr.

In treating, by the method of quaternions, the question which forms the basis of *Minding's Theorem*, I had the advantage of being guided by Professor Tait's paper on that subject (*T. R. S. E.*, 1880), and it is only by varying his method that I could hope to present the question under a new aspect.

§ 1.

Let us apply the operator

$$p(\ )q$$

of a conical rotation, where $q = p^{-1}$, to a system of given vector-forces β_0, β_0', β_0'', &c., p being a versor, the results of the rotation being β, β', &c., respectively.

By the expressions

$$(1) \qquad \beta = p\beta_0 q\,, \ \beta' = p\beta'_0 q\,, \ \&c.,$$

we submit the forces at once to two of Minding's conditions; namely, 1^0 the magnitude of each of the forces remains unchanged by the rotation, and 2^0 the mutual inclinations of the forces, considered two by two, remain also unvaried.

The resultant of the forces being

$$\Sigma\beta = p(\Sigma\beta_0)q\,,$$

remains also unchanged as to its tensor, and we may, without loss of generality, assume at once that the unit of force has been chosen so as to give

$$\mathrm{T}\Sigma\beta = 1 = \mathrm{T}\Sigma\beta_0\,.$$

We put

$$\begin{cases} \mathrm{U}\Sigma\beta = k' \\ \mathrm{U}\Sigma\beta_0 = k'_0\,. \end{cases}$$

This gives

$$(2) \qquad k' = pk'_0 q\,.$$

We call α, α', α'', &c., the vectors drawn from a certain origin to the points of application of the forces. A *third* condition will be the rigidity of the system of these vectors, so that they remain immobile in respect to one another, and to their origin.

The *fourth* condition to which *Minding's System of Forces* are to be submitted demands that the action of the system be reduced to that of a single force, and consequently that the moment of the resulting couple $\Sigma\mathrm{V}.\alpha\beta$, in respect to the origin, be perpendicular to the direction of the resultant of the forces.

This condition, expressed by

$$(3) \qquad \mathrm{S}k'\Sigma\mathrm{V}\alpha\beta = 0\,,$$

or in virtue of (1) and (2) by

$$\Sigma\mathrm{S}\alpha p(\mathrm{V}\beta_0 k'_0)q = 0\,,$$

constitutes a relation between the data α, α', &c., β_0, β'_0, &c., k_0', on the one hand, and between the *three* scalar elements of the versor p on the other: by this relation (3) the number of the arbitrary scalar elements of the question becomes reduced to *two.* Obviously the scalar elements on which the unit-vector k' depends are also two in number; but as the system may, in virtue of the variations of $p(\quad)q$, possibly turn round the very direction of k', it will be more convenient to consider the elements of $p(\quad)q$ as the true independent parameters, at least two of them.

§ 2.

The position of the single resultant of the system will be that of the straight line

$$\Sigma \mathrm{V}(\alpha - \rho)\beta = 0, \tag{4}$$

where ρ designates the vector of a point of that line, the origin of ρ being the same with that of the vectors α, α', . . .

Having

$$\Sigma \mathrm{V}\rho\beta = \mathrm{V}\rho\Sigma\beta = \mathrm{V}\rho k',$$

and putting generally, with Professor Tait,

$$\left\{\begin{aligned} \phi\omega &= \Sigma\alpha \mathrm{S}\beta\omega, \\ \phi'\omega &= \Sigma\beta \mathrm{S}\alpha\omega, \end{aligned}\right. \tag{5}$$

we get the solution of (4) by

$$\rho = \phi' k' - \phi k' + uk'$$

where u is an arbitrary scalar on which the position of the extremity of ρ on the line depends.

We remark now that $\phi k'$, owing to $pq = 1$, becomes

$$\phi k' = \Sigma\alpha \mathrm{S}p\beta_0 qpk'_0 q = \Sigma\alpha \mathrm{S}\beta_0 k_0;$$

namely, $\phi k'$ will be constant in direction and value, whatever be the state of rotation of the system.

This result permits of a change of origin of the vectors α, α', &c., and ρ, by which the *new* value of $\phi k'$ will vanish. The new origin will be at the extremity of the former $(-\phi k')$. This change of origin will not affect $k' = \Sigma\beta$, but it will change the vector moment.

Not to change notations, we assume that the origin O was from the beginning at the point for which

$$o = \phi k' = \Sigma\alpha \mathrm{S}\beta_0 k'_0. \tag{6}$$

This origin, which is analogous to the centre of a system of parallel forces, has been called by Minding *the central point* of a system of non-parallel forces.

We have now, owing to (6),

$$\rho = (\phi' + u)k' . \tag{7}$$

We also designate by η the vector moment of the forces in respect to the origin now chosen, so that

$$\eta = \Sigma \mathrm{V}\alpha\beta ; \tag{8}$$

and the condition (3) will be

$$\mathrm{S}k'\eta = 0 . \tag{9}$$

Owing to the definitions (5) and (8) we have now generally for any vector ω,

$$(\phi - \phi')\omega = \mathrm{V}\eta\omega . \tag{10}$$

Hence for $\omega = k'$, by (6),

$$-\phi' k' = \mathrm{V}\eta k' ,$$

In virtue of (9) this becomes simply,

$$\phi' k' = k'\eta . \tag{11}$$

From this, and from (6), we deduce

$$\mathrm{S}\eta\phi' k' = 0 , \text{ and } \mathrm{S}k'\phi' k' = 0 .$$

These relations show that the direction of k', η, $\phi' k'$ are trirectangular, and that

$$\mathrm{T}\phi' k' = \mathrm{T}\eta . \tag{12}$$

§ 3.

Let i', j', be two unit-vectors forming a trirectangular system with k', and let i'_0, j'_0 be their initial directions, so that

$$i' = p i'_0 q , \; j' = p j'_0 q .$$

From

$$\rho = - i'\mathrm{S}i'\rho - j'\mathrm{S}j'\rho - k'\mathrm{S}k'\rho$$

we deduce, owing to (6),

$$\phi\rho = - \phi i'\mathrm{S}i\rho - \phi j'\mathrm{S}j'\rho ,$$

where the results $\phi i'$, $\phi j'$ are constants for the same reason as $\phi k'$.

Owing to (6) the coefficients of the cubic may be expressed by

$$(13)\qquad \begin{cases} m\ = 0, \\ m_1 = -\mathrm{S}k'\phi i''\phi j'', \\ m_2 = -(\mathrm{S}i''\phi i'' + \mathrm{S}j''\phi j). \end{cases}$$

We have now from (7)

$$k' = (\phi' + u)\rho^{-1};$$

and putting

$$(14)\qquad m_u = +m_1 u + m_2 u^2 + u^3,$$

we get

$$m_u k' = [m\phi'^{-1} + u(m_2 - \phi') + u^2]\rho.$$

The term $m\phi^{-1}\rho$ being indeterminate, owing to $m=0$, we consider

$$m\phi'^{-1}\mathrm{V}\lambda\mu = \mathrm{V}\phi\lambda\phi\mu;$$

and putting $\mathrm{V}\lambda\mu = \rho$, we get

$$(m\phi'^{-1}\rho) = -\mathrm{V}\phi i''\phi j''\mathrm{S}k'\rho$$

(See also *Proc. R. S. E.*, Dec. 1880, on the case $m=0$).

We remark that by (7) we have

$$\mathrm{S}k'\rho = -u.$$

Substituting this in the preceding term we get

$$(15)\qquad \frac{m_u}{u}k' = \mathrm{V}\phi i''\phi j'' + (m_2 + u)\rho - \ '\rho.$$

Effecting the combination

$$\left(\frac{m_u}{u}k' + \phi'\rho\right)^2 - \left(\mathrm{V}\phi i''\phi j'' + (m_2 + u)\rho\right)^2 = 0,$$

and remarking $\mathrm{S}k'\phi'\rho = \mathrm{S}\rho\phi k' = 0$, we get

$$(16)\qquad \begin{cases} 0 = (\phi'\rho)^2 - \left(\dfrac{m_u}{u}\right)^2 - \mathrm{V}^2\phi i''\phi j' - (m_2 + u)^2\rho^2 \\ \qquad\qquad - 2(m_2 + u)\mathrm{S}\rho\phi i''\phi j''. \end{cases}$$

We obtain a relation between $\frac{m_u}{u}$ and $(m_2 + u)$ independent of m_1. Namely, we introduce into $\mathrm{S}k'\eta = 0$ the value

$$\eta = \mathrm{V}(i''\phi i'' + j''\phi j'').$$

This gives

$$(17) \qquad \mathrm{S}j''\phi i'' = \mathrm{S}i''\phi j''\,.$$

By the use of this equality the value (13) of m_1 becomes

$$m_1 = \mathrm{SV}j''i''\mathrm{V}\phi i''\phi j''$$

$$= \mathrm{S}j''\phi j''\mathrm{S}i''\phi i'' - \mathrm{S}j''\phi i''\mathrm{S}i''\phi j''\,,$$

the last term being now a square in virtue of (17). We also observe that

$$\phi' k' = -i''\mathrm{S}i''\phi' k' - j''\mathrm{S}j''\phi' k'$$

$$= -i''\mathrm{S}k'\phi i'' - j''\mathrm{S}k'\phi j''\,.$$

Introducing these values, and that of m_2 into the sum

$$m_2^2 - 2m_1 - (\phi' k')^2\,,$$

the result will be

$$\mathrm{S}^2 i'\phi i'' + \mathrm{S}^2 j'\phi i'' + \mathrm{S}^2 k'\phi i''$$

$$+ \mathrm{S}^2 i'\phi j'' + \mathrm{S}^2 j'\phi j'' + \mathrm{S}^2 k'\phi j''\,,$$

namely,

$$-(\phi i'')^2 - (\phi j'')^2\,.$$

We put

$$(18) \qquad \begin{cases} \mathrm{M}_2 = \mathrm{T}^2\phi i'' + \mathrm{T}^2\phi j''\,, \\ \mathrm{M}_1 = \mathrm{T}^2\mathrm{V}\phi i''\phi j''\,, \end{cases}$$

and the relation will be

$$(19) \qquad m_2^2 - 2m_1 - (\phi' k')^2 = \mathrm{M}_2\,.$$

Further, by (7) we get

$$(\phi' k')^2 = \rho^2 + u^2\,.$$

Substituting this into (19), and adding and subtracting $2m_2u + u^2$, we get

$$(20) \qquad (m_2 + u)^2 - 2\frac{m_u}{u} - \rho^2 = \mathrm{M}_2\,.$$

Hence also

$$(m_2 + u)^2\rho^2 + \left(\frac{m_u}{u}\right) = \left(\frac{m_u}{u} + \rho^2\right)^2 + \mathrm{M}_2\rho^2.$$

The equation (16) now takes the form

$$(21)\qquad \left\{\begin{matrix}(\phi'\rho)^2 - \mathrm{M}_2\rho^2 - \left(\dfrac{m_u}{u} + \rho^2\right)^2 + \mathrm{M}_1 \\ -\,2(m_2+u)\mathrm{S}\rho\phi i''\phi j''\end{matrix}\right\} = 0\,,$$

where (m_2+u) depends on $\left(\dfrac{m_u}{u} + \rho^2\right)$ by

$$(22)\qquad (m_2+u)^2 = \mathrm{M}_2 - \rho^2 + 2\left(\frac{m_u}{u} + \rho^2\right).$$

§ 4.

The relation (21) depends through (22) explicitly on $\left(\dfrac{m_u}{u} + \rho^2\right)$ and on ρ only. The term $(\phi'\rho)^2 = \mathrm{S}\rho\phi\phi'\rho = \mathrm{S}\rho\varpi\rho$ depends on ρ only and on the constant vectors $\phi i''$, $\phi j''$, because we have

$$\phi'\rho = -\Sigma i''\mathrm{S}i\phi'\rho = -\Sigma i''\mathrm{S}\rho\phi i'\,;$$

hence

$$(23)\qquad \phi\phi'\rho = \varpi\rho = -(\phi i''\mathrm{S}\rho'\phi i'' + \phi j''\mathrm{S}\rho\phi j'').$$

Through (13) and (14) the quantity $\dfrac{m_u}{u}$ contains the three arbitraries of the question, namely, u, and the two independent parameters of the operator $p(\quad)q$.

The equation (21) represents now, by the extremity of ρ, any point on the resulting force of the system in any of its positions.

If we submit the three just named arbitraries to a relation of condition, then we "pick out" so to say a particular point on every one of the resultants, and the aggregate of these points will form a definite surface.

The equation of condition which gives the surface of the lowest possible degree will be of course $\dfrac{m_u}{u} + \rho^2$ = a constant parameter.

For convenience sake we put

$$(24)\qquad \left\{\begin{aligned} &h + \frac{m_u}{u} + \rho^2 = 0\,, \\ &g + m_2 + u = 0\,, \end{aligned}\right.$$

$-h$ being the parameter introduced (h being identical with the x

of Professor Tait's paper), and g depending on h through (22) which becomes

$$g^2 + 2h = \mathrm{M}_2 - \rho^2 . \tag{25}$$

The equation of the surface will be

$$\left\{ \begin{matrix} \mathrm{S}\rho\varpi\rho - \mathrm{M}_2\rho^2 + \mathrm{M}_1 - h^2 \\ + 2g\mathrm{S}\rho\phi i'\phi j' \end{matrix} \right\} = 0 , \tag{26}$$

and the elimination of g by (25) will raise the degree in ρ to the 4th.

This equation is concordant with that numbered (10) of Professor Tait's paper: this last one is transformable into ours (26) by the elimination of t (which is our $-m_2$). The elimination can be founded on the equation (9) of the quoted paper, and by treating by $\mathrm{S}.\phi i'\phi j'$ the equation (8′) so as to give (in our notation)

$$hm_1 - m_2\mathrm{S}\rho\phi i'\phi j' + \mathrm{M}_1 = 0 .$$

The value resulting for t (or of our m_2) will be in our notation

$$m_2 n = \mathrm{H} ,$$

n containing then a double signed radical, but, as we shall find, the sign of it will be definite, and (in *anticipation* to our own use) we state that we shall have

$$\begin{aligned} n &= gh + \mathrm{S}\rho\phi i'\phi j' \\ \mathrm{H} &= h^2 - \mathrm{M}_2 h + \mathrm{M}_1 . \end{aligned} \tag{27}$$

If, on the contrary, we wish to form the equation of the locus of the feet of perpendiculars from the origin on the single resultants, then we are no more free to establish a relation between the parameters of $p(\quad)q$ and u. The condition of the perpendicularity between the line (7) and ρ itself will be

$$\mathrm{S}k'\rho = 0 .$$

The equation (7) will give its *first* scalar relation

$$u = 0 . \tag{28}$$

Then (21) with this value of u will constitute a *second* scalar relation (equivalent with $k'^2 = -1$).

A *third* scalar relation will be obtained in treating by $\mathrm{S}(\quad)\phi i'\phi j'$ not (7) itself, but a transformation of it derived from (15). Finally, we have the condition (17) equivalent with $Sk'\eta = 0$. We have thus *four* equations between the three parameters of $p(\ \ )q$ by which to eliminate (theoretically at least) these parameters, and the result will be an equation in ρ representing a *definite surface.*

Practically the elimination may be effected by eliminating h_0, g_0 [h_0, g_0 being the values of h, g in the relations (24) for $u = 0$] from (25), (26), and the third scalar relation spoken of derived from (15). We reserve this question for another occasion.

§ 5.

Let us now transform the expression (15) of k' so as to render it dependent on h and ρ alone.

Taking the function ϕ' of both members we get

$$(29) \qquad 0 = -\frac{m_u}{u}\phi' k' + (m_2 + u)\phi'\rho - \phi'^2\rho,$$

because $\phi' . V\phi i' \phi j' = 0$, by considering (23).

By (10) and (11) we have

$$(\phi - \phi')\phi'\rho = V\eta\phi'\rho = V . \phi' k' k' \phi' \rho .$$

And considering that $Sk'\phi'\rho = S\rho\phi k' = 0$, developing $V . \phi' k' k' \phi' \rho$, and replacing $\phi' k'$ by $\rho - uk'$, we get

$$\phi'^2\rho = \phi\phi'\rho + k' S\rho\phi'\rho .$$

We get $S\rho\phi'\rho$ by treating (15) by $S . \rho$. This gives, by $Sk\rho' = -u$,

$$S\rho\phi'\rho = m_u + S . \rho\phi i' \phi j' + (m_2 + u)\rho^2.$$

In (29) also we replace $\phi' k'$ by $\rho - uk'$ and eliminate $\phi'\rho$ between (29), so modified, and (15). This gives

$$\begin{aligned} 0 = &-\frac{m_u}{u}(\rho - uk') \\ &+ (m_2 + u)\left[-\frac{m_u}{u}k' + V\phi i' \phi j' + (m_2 + u)\rho \right] \\ &- \phi(\phi'\rho) - k'[m_u + S\rho\phi i' \phi j' + (m_2 + u)\rho^2] . \end{aligned}$$

With the notations of g, h, n (24), (27), this becomes

$$(30) \qquad 0 = nk' + \varpi\rho + (h - M_2)\rho - V\phi i' \phi j' g ,$$

g being related to h by (25) and n given by (27).

The equations (26) and (30) solve the question of finding the positions of the resultant force for any given point of space. When namely, ρ is given, the scalar-equation (26) will give theoretically *four* values of h, after the elimination of g by (25), and the vector-equation will give the four directions k' corresponding.

Before attacking this question we will find it very convenient to have to deal with rectangular coordinates, and we make use of one of the solutions of Professor Tait's of the equation of condition,

$$(31) \qquad 0 = S\phi i''\phi j'' = Sj''(\phi'\phi)i'' = Si''(\phi'\phi)j''.$$

We consider, namely, $\phi i''$, $\phi j''$ by their expressions

$$\begin{aligned} \phi i'' &= \Sigma' a S\beta i'' = \Sigma a S\beta_0 i''_0 \\ \phi j'' &= = \Sigma a S\beta_0 j_0 , \end{aligned}$$

and designating in particular

$$\Sigma a S\beta_0 \omega \text{ by } \phi_0 \omega$$

we take for i''_0, j''_0 the solutions of the equation

$$V\omega(\phi'_0\phi_0)\omega = 0 ,$$

the third being k'_0.

The function $(\phi'_0\phi_0)$ is self-conjugate, and its principal axes are at right angles to one another; we designate by i''_0, j''_0 perpendicular to k'_0, the unit vectors in the direction of these axes. The cubic, reduced to a quadric (because of $\phi'_0 k'_0 = 0$), corresponding will be

$$w^2 - M_2 w + M_1 = 0 .$$

Calling a, b, the absolute values of $\phi_0 i''_0$, $\phi j''_0$, we have by (18)

$$(32) \qquad \begin{cases} M_2 = a^2 + b^2 , \\ M_1 = a^2 b^2 , \end{cases}$$

because now $V\phi_0 i''_0 \phi_0 j''_0 = \phi_0 i''_0 \phi_0 j''_0$ owing to (31).

We have therefore

$$(\phi'_0\phi_0)i''_0 = i''_0 a^2 , \quad (\phi'_0\phi_0)j''_0 = j''_0 b^2 .$$

We now call i, j, k, the system of trirectanglar unit vectors in the directions of $\phi_0 i''_0$, $\phi_0 j''_0$, and of $V\phi_0 i''_0 \phi_0 j''_0 = \phi_0 i'' \phi_0 j''_0$. This gives us

$$(33)\qquad \left\{\begin{array}{r@{}l@{}l} \phi i' &= ia &= \phi_0 i'_0 , \\ \phi j' &= jb &= \phi_0 j'_0 , \\ \phi i' \phi j' &= kab &= \phi_0 i'_0 \phi_0 j'_0 , \\ \phi k' &= 0 &= \phi_0 k_0 . \end{array}\right.$$

Comparing $(\phi'_0\phi_0)i'_0 = i'_0 a^2$, with $\phi'_0(\phi_0 i'_0) = a\phi'_0 i$, &c., we get the corresponding relations

$$\phi'_0 i = i'_0 a , \ \phi'_0 j = j_0 b .$$

But generally we have

$$\phi'\omega = \Sigma\beta \mathrm{S}\alpha\omega = p(\Sigma\beta_0 \mathrm{S}\alpha\omega)q = p(\phi'_0\omega)q .$$

Hence forming i', j', by applying the operator $p(\quad)q$ to i'_0, j'_0 (as it has already (2) been applied to k'_0 for obtaining k'), we get

$$(34)\qquad \left\{\begin{array}{r@{}l} \phi' i &= i'a , \\ \phi' j &= j'b , \\ \phi' i \phi' j &= k'ab , \\ \phi' k &= 0 . \end{array}\right.$$

Here the unit vectors i, j, k, represent directions which are invariably fixed, whereas i', j', k' rotate with the forces β, β', &c.

§ 6.

We introduce now

$$\rho = ix + jy + kz ,$$

x, y, z, being the Carthesian coordinates of the point ρ on the single resultant of the system of forces, these coordinates being referred to axes which are fixed in space, and passing through the central point of the system.

We have also, by introducing (33) into the expression (23) of $\phi\phi'\rho$,

$$(35)\qquad \left\{\begin{array}{l} \phi\phi'\rho = \varpi\rho = -ia^2\mathrm{S}i\rho - jb^2\mathrm{S}j\rho \\ \qquad\qquad\quad = ia^2x + jb^2y . \end{array}\right.$$

By this the equations (26) and (30) become

$$(36)\qquad \left\{\begin{array}{l} b^2x^2 + a^2y^2 + \mathrm{M}_2 z^2 + \mathrm{M}_1 - h^2 \\ \qquad - 2gabz \end{array}\right\} = 0 ,$$

and

$$(37)\qquad \begin{cases} -nk' = ix(h-b^2) + jy(h-a^2) \\ \qquad + k[z(h-\mathrm{M}_2) + gab]\,, \end{cases}$$

where now (by (27))

$$(37\ bis)\qquad n = gh - abz\,;$$

g^2 being expressed by (25), becomes

$$(36\ bis)\qquad g^2 = \mathrm{M}_2 - 2h + x^2 + y^2 + z^2\,.$$

We abandon the problem of discussing the roots h as expressed in function of xyz, when the elements of ρ are given alone. But we will consider what surfaces the equation (36) represents when h being considered as a parameter receives any value between $-\infty$ and $+\infty$.

The equation (36) when freed of the radical represented by g will be biquadratic in x, y, z. We resolve in respect to z. Putting

$$b^2x^2 + a^2y^2 + \mathrm{M}_1 - h^2 = \mathrm{G}'\,,$$

$$x^2 + y^2 + \mathrm{M}_2 - 2h = g'\,,$$

we get the equation under the form

$$(\mathrm{M}_2z^2 + \mathrm{G}')^2 - 4z^2\mathrm{M}_1(z^2 + g') = 0\,.$$

The coefficient of z^4 being

$$\mathrm{M}_2^2 - 4\mathrm{M}_1 = (a^2 - b^2)^2\,,$$

we introduce c by

$$a^2 - b^2 = c^2\,,$$

and, without loss of generality, we assume $a > b$ *once for all*, so that c be real.

We have now, in resolving in respect to z^2

$$c^4z^2 = (2\mathrm{M}_1g' - \mathrm{M}_2\mathrm{G}') \pm \mathrm{R}\,,$$

where we put

$$\mathrm{R}^2 = (2\mathrm{M}_1g' - \mathrm{M}_2\mathrm{G}')^2 - c^4\mathrm{G}'^2\,.$$

This being the difference of squares, and as in virtue of (32)

$$\mathrm{M}_2 - c^2 = 2b^2$$

$$\mathrm{M}_2 + c^2 = 2a^2\,,$$

we transform R^2 into

$$\mathrm{R}^2 = 4a^2b^2(a^2g' - \mathrm{G}')(b^2g' - \mathrm{G}')\,.$$

Also

$$2\mathrm{M}_1g' - \mathrm{M}_2\mathrm{G}' = b^2(a^2g' - b') + a^2(b^2g' - \mathrm{G}')\,.$$

By the values of G', g', we get

$$(38)\qquad \begin{cases} X^2 = a^2g' - G' = c^2x^2 + (a^2 - h)^2, \\ Y^2 = b^2g' - G' = -c^2y^2 + (b^2 - h)^2, \end{cases}$$

where we introduce the letters X^2, Y^2, as abbreviations.

We have now

$$c^4z^2 = c^2X^2 + a^2Y^2 \pm 2abXY.$$

The second member being a square we deduce

$$(39)\qquad c^2z = \pm bX \pm aY,$$

the double signs being independent from each other, and the four values of the second member constitute the four roots z as functions of x, y and the parameter h, satisfying (36).

§ 7.

For the construction of ρ we introduce

$$\rho' = ix + kz',$$
$$\rho'' = jy + kz'',$$

where z', z'' represent the two terms of z respectively, say

$$c^2z' = \pm bX, \quad c^2z'' = \pm aY;$$

the double signs showing the possibility for z' and z'' to represent positive and negative values like any other coordinate.

We have then

$$\rho = \rho' + \rho''.$$

If, for a given value of h (leaving out for the present the values $h = a^2$, and $h = b^2$), we construct ρ' and ρ'' separately we get by the former a hyperbola, and by the second an ellipse. The planes of these curves will be *at right angles.* In ordinary coordinates the equations of these curves will be

$$\left[\frac{z'}{\left(\frac{h-a^2}{c}\right) \times \frac{b}{c}}\right] - \left[\frac{x}{\left(\frac{h-a^2}{c}\right)}\right] = 1,$$

$$\left[\frac{z''}{\left(\frac{h-b^2}{c}\right) \times \frac{a}{c}}\right]^2 + \left[\frac{y}{\left(\frac{h-b^2}{c}\right)}\right]^2 = 1.$$

If we take the point ρ' of the hyperbola for the centre of the ellipse ρ'', then the sum $\rho'+\rho''=\rho$ will represent a surface which we may call a hyperbolic *Tore*, that is a hollow canal having everywhere the same elliptical section, parallel namely to the plane j, k, of the ellipse ρ'', and *equal* to that ellipse; whereas the median line of the canal will be the hyperbola ρ' in the plane i, k.

The two tores corresponding to the two branches of the same hyperbola will be symmetrical in respect to the plane i, j, passing through the centre (at the origin O). The two sheets of the same surface may intersect or not according as the value of h is outside the interval between a^2 and b^2 or inside that interval.

We will not here undertake to prove that through every point of space there must be four surfaces passing, corresponding to four different values of h; we will only remark that the same hyperbola will correspond to two different values of h, namely, h and h' satisfying to

$$h-a^2=a^2-h'.$$

To these values correspond two different ellipses. *Vice versa*, to

$$h-b^2=b^2-h'',$$

for the same ellipse correspond two different hyperbolas . . .

All the hyperbolas have the same pair of asymptotes; these lines pass through the origin and have the directions of δ, δ', defined by

$$a\delta=ic+kb\,,\quad a\delta'=-ic+kb\,.$$

Considering now the cases of $h=a^2$ and $h=b^2$, we must remember our assuming of the inequality

$$a>b\,.$$

In the case $h=a^2$ the two tores transform themselves into two right cylinders, having their axes coincident with the asymptotes just mentioned; their radius perpendicular to the axis $=\sqrt{a^2-b^2}=c$. This will easily appear when we consider the value of z becoming for $h=a^2$

$$cz=\pm bx\pm a\sqrt{c^2-y^2},$$

hence

$$(40)\qquad (cz\mp bx)^2+a^2y^2=a^2c^2.$$

We may introduce

$$\begin{cases} j\delta = \gamma = \dfrac{1}{a}(ib - kc), \\ j\delta' = \gamma' = \dfrac{1}{a}(ib + kc). \end{cases}$$

When the equations become for γ and γ',

$$S^2\gamma\rho + S^2j\rho = c^2,$$

which leaves the component of ρ parallel to δ, or to δ', indeterminate.

These two cylinders intersect in the planes (j, k) and (i, j). In the first of these planes the equations become

$$(41) \qquad x = 0, \text{ and } \left(\frac{z}{a}\right)^2 + \left(\frac{y}{b}\right)^2 = 1,$$

an ellipse which in the next section we will meet again as *Minding's Ellipse.* The second intersection

$$z = 0, \left(\frac{x}{ac : b}\right)^2 + \left(\frac{y}{c}\right)^2 = 1,$$

has not received, as yet, any physical signification.

In the case of $h = b^2$, or, as we will put it

$$h - b^2 = \text{an infinitely small value,}$$

the values of Y in the expression (39) of z will be real for values of y^2 which do not outpass the limit

$$\left(\frac{h - b^2}{c}\right)^2,$$

and therefore the "tore-surface" represented by $\rho = \rho' + \rho''$ will shrink into an infinitesimally narrow canal embracing the hyperbola represented by

$$\rho' = ix + kz',$$

where we have

$$(42) \qquad y = 0, \text{ and } \left(\frac{z'}{b}\right)^2 - \left(\frac{x}{c}\right)^2 = 1.$$

This tore-surface, like all others represented by (39), contains at every one of its points *one* point of the single resultants of the system (generally four of which are passing through every point of space); and the different points of the surface represent the corresponding points of the resultant in the different states of rotation of the system.

To the question, if every one of the surfaces (39) has one point in common with *every one* of the resultants, we give the answer in § 9, where we show that through every point of space we are able to draw four straight lines meeting the hyperbola (42), and which satisfy moreover the conditions derived from the expression of k'.

We have thus the proof of one part of *Minding's Theorem* as announced at page 37 of *Crelle's Math. Journal*, vol. xv., namely, the resultant in the different, innumerable, positions which it may take, passes constantly through the hyperbola which is the limit of the infinitesimally narrow canal corresponding to $h-b^2=0$.

The proofs of the other propositions of the theorem will be gained by the examination of the directions k' of the single resultant.

§ 8.

Writing again the expression (37) containing k',

$$\begin{aligned}0=nk'+ix(h-b^2)&+jy(h-a^2)\\&+k[z(h-\mathrm{M}_2)+gab],\end{aligned}$$

we introduce into it the hypothesis

$$h-b^2 = \text{an infinitely small value.}$$

For the preparation of n and g as defined in (36 *bis*) and (37 *bis*) we have the relations

$$(43)\qquad \begin{cases}(ga-bz)^2=\mathrm{X}^2,\\(az-gb)^2=\mathrm{Y}^2,\end{cases}$$

which become identities if we substitute into them the value of g^2 (36 *bis*) and the value of $2gabz$ drawn from (36), and having regard to (32) and (38).

As the value of y is to converge to zero, at the same time as $h-b^2$, but independently of it, we put

$$cy=w(h-b^2),$$

calling w an arbitrary scalar.

We have by (43)

$$gb=az-\mathrm{Y}f,$$

where the letter f is to stand for either $+1$ or -1 as the case may afford. This gives by (36 *bis*)

$$n = \frac{1}{b}\,(gbh - b^2az)$$

$$= \frac{1}{b}[(h - b^2)az - hYf]\,.$$

Introducing the value y into Y (38) we get

$$Yf = (h - b^2)\sqrt{1 - w^2}\,.$$

As we need only the terms of the first order in $(h - b^2)$ we may replace hY by b^2Y. Thus

$$n = \frac{1}{b}\,(h - b^2)\left[az - b^2\sqrt{1 - w^2}\right]$$

$$n = (h - b^2)\left[\frac{az}{b} - b\sqrt{1 - w^2}\right].$$

The coefficient of k in (37) becomes

$$z(h - M_2) + a\,.\,bg = [h - M_2 + a^2]z - (h - b^2)a\sqrt{1 - w^2}\,;$$

and considering the value of M_2 the coefficient of z will be $(h - b^2)$.

Also in the term $jy(h - a^2)$ we replace y by

$$(h - b^2)\,\frac{w}{c}\,.$$

The term becomes, for $h - a^2 = b^2 - a^2 = -c^2$,

$$(h - b^2)\,\frac{w}{c}\,(b^2 - a^2) = -(h - b^2)wc\,.$$

We have now the factor $(h - b^2)$ existing in evidence in all the terms of the relation (37), which becomes rigorously as to the first order in $(h - b^2)$,

$$0 = (h - b^2)\left[\begin{array}{c} k'\left[\dfrac{az}{b} - b\sqrt{1 - w^2}\right] \\ + ix - jcw + k(z - a\sqrt{1 - w^2}) \end{array}\right].$$

As the second member represents the terms of the first order in $(h - b^2)$, and as $h - b^2$ is variable, we are entitled to equate the factor of $h - b^2$ separately to zero.

Before writing the equation we remark that the arbitrary quantities

$$cw\,,\ \text{and}\ a\sqrt{1-w^2}\,,$$

when substituted into the place of y and z respectively in the equation (41) of the ellipse, satisfy that equation identically. We introduce the coordinates y_2, z_2, as those of a point of the ellipse, putting $x_2=0$, and

$$y_2=cw\,,\ z_2=a\sqrt{1-w^2}\,.$$

Also for distinguishing the coordinates of the hyperbola from those of any point in space we replace x, z', in (42) by x_1, z_1, putting $y_1=0$.

The equation in k' now takes the form

$$\left\{\begin{aligned} 0=k'\left[\frac{az_1}{b}-\frac{bz_2}{a}\right]& \\ +ix_1-jy_2+k(z_1-z_2)&\,; \end{aligned}\right.$$

or, if we introduce

$$(44)\quad \left\{\begin{aligned} &\sigma_1=ix_1+kz_1\,,\quad \left(\frac{z_1}{b}\right)^2-\left(\frac{x_1}{c}\right)^2=1\,,\\ &\sigma_2=jy_2+kz_2\,,\quad \left(\frac{z_2}{a}\right)^2+\left(\frac{y_2}{c}\right)^2=1\,,\\ &\mathrm{N}=\frac{az_1}{b}-\frac{bz_2}{a}\,,\quad y_1=0\,,\ x_2=0\,, \end{aligned}\right.$$

we have

$$(45)\qquad k'=\frac{1}{\mathrm{N}}(\sigma_2-\sigma_1)\,.$$

This establishes the second part of *Minding's Theorem,* namely, *all the single resultants pass through the ellipse* because every point of the hyperbola is the summit of a cone, of which the generating lines are the single resultants passing through that point, and the ellipse forms the oblique base of the cone, and *vice versa* every point of the ellipse is the summit of another cone of which the base is formed by the two branches of the hyperbola: moreover, *all these cones are right cones, the axes being the tangent to the curve* at the point where the summit of the cone is situated,—this latter proposition results from the equation of the cone, as, for example, in the case of its summit being in σ_1 on the hyperbola, when it will be of the form

$$V.^2\theta(\rho-\sigma_1)-c^2(\rho-\sigma_1)^2=0\,,$$

where

$$\theta=-i\frac{c}{b}\,Sk\sigma_1+k\frac{b}{c}\,Si\sigma_1\,,$$

and ρ being now the vector of any point on the line $\sigma_2-\sigma_1$ or its prolongations.

The last part of Minding's propositions is proved by the comparison of the values of the focal distances of the hyperbola and the ellipse, these being

$$\sqrt{b^2+c^2}=a\,,\ \text{and}\ \sqrt{a^2-c^2}=b$$

respectively, with the corresponding great axes, these being

$$b\ \text{and}\ a\,.$$

It follows also, from the expressions (44) of the vectors of the hyperbola and the ellipse, that the planes of these curves are at right angles, the line of intersection of the planes passing through the centre of these concentric curves.

§ 9.

We will finally show that the variable vectors σ_1, σ_2, are very convenient auxiliaries for expressing the solutions of the equation of the fourth degree on which h depends, namely, of the equation (36) from which g has been eliminated by the help of (36 *bis*).

We will not treat of that equation, but we consider the vector equation (37), from which it can be deduced as one of its scalar equations.

Let ρ designate a point on the line $\sigma_2-\sigma_1$ or its prolongations, so that we have

$$\rho=\sigma_1+k't\,.$$

We have then the two vector equations

$$\frac{\rho-\sigma_1}{t}=\frac{\sigma_2-\sigma_1}{N}=\begin{bmatrix} ix(h-b^2)+jy(h-a^2) \\ +k\{z(h-M_2)+gab\} \end{bmatrix}\times\left(\frac{-1}{n}\right).$$

Taking the scalars $S.i$, $S.j$, $S.k$, we get six equations, which form only four distinct ones, because they satisfy *à priori* to $k'^2 = -1$, and to $N^2 = -(\sigma_2 - \sigma_1)^2$. From these equations we easily deduce

$$h = b^2 + c^2\left(\frac{t}{N}\right)$$

and also

$$\frac{t}{N} = S\left(\frac{\rho - \sigma_1}{\sigma_2 - \sigma_1}\right),$$

where we employ the sign S (placed before the quotient of two parallel vectors) simply for preserving the algebraical sign of the quotient.

If we assume σ_1 and σ_2 to be given, then the expression

$$h = b^2 + c^2 S \frac{\rho - \sigma_1}{\sigma_2 - \sigma_1} \tag{46}$$

will represent the values of h for any point ρ situated on the line $\sigma_2 - \sigma_1$, and the coordinates x, y, z of that point, together with the resulting value of h, will satisfy the equation of the fourth degree spoken of.

If we assume ρ to be given, namely, x, y, z to be given, then the question would be to determine first σ_1 and σ_2 independently of h, and this would again lead to an equation of the fourth degree in one of the coordinates x_1, z_1, or y_2, z_2, and the question as to the reality of the roots would still arise in all its complication.

Instead of following that course, we may by geometrical considerations, and with the help of (46), assure ourselves that for every point of space there exist four corresponding lines $\sigma_2 - \sigma_1$, and consequently four values of h which satisfy to the equation in k', and consequently to the scalar equation deduced from it.

Let us suppose that the two Minding's curves be constructed in their relative position in space, and let them consist of a rigid material. Then drawing a straight line through the extremity M of ρ we may turn that line until it strikes, say, one branch of the hyperbola, then we move the line on, without detaching it from the hyperbola, until it strikes a point E of the ellipse, the point of the hyperbola being H. Then we have a first position of the line $\sigma_2 - \sigma_1$, and a corresponding value of h and of k'.

But we remark that if the points are following each other in the order say

$$\mathrm{M}, \mathrm{H}, \mathrm{E},$$

there will exist another position of the line in which it strikes the ellipse first, and further on the hyperbola, so that we have a second line $\sigma_2 - \sigma_1$, corresponding to the disposition of either

$$\mathrm{M}, \mathrm{E}', \mathrm{H}',$$

or, may be, if the first had been

$$\mathrm{H}, \mathrm{M}, \mathrm{E},$$

then there would be a second disposition

$$\mathrm{M}, \mathrm{H}', \mathrm{E}'.$$

But we may repeat this reasoning in taking into account the other branch of the hyperbola, and so we get four systems of positions of the line $\sigma_2 - \sigma_1$ and four corresponding values of h, these being real of necessity, because their expression is dependent on the real lines $\rho - \sigma_1$, and $\sigma_2 - \sigma_1$ in

$$h = b^2 + c^2 \mathrm{S} \frac{\rho - \sigma_1}{\sigma_2 - \sigma_1}.$$

We see also by this expression that the points corresponding to the value $h = a^2$ can be placed only on one of the cylinders (40), because, apart from the value $\rho = \sigma_2$, which places ρ on the *intersection* of both the cylinders, we have also the points ρ for which we have generally

$$\mathrm{S} \frac{\rho - \sigma_1}{\sigma_2 - \sigma_1} = 1, \ \therefore h = b^2 + c^2 = a^2.$$

As $\rho - \sigma_1$ and $\sigma_2 - \sigma_1$ are to have the same direction, the condition can only be satisfied (excepting always $\rho = \sigma_2$) when σ_1 becomes infinite along the hyperbola. In this case $\rho - \sigma_1$ takes the direction parallel to the asymptotes, and therefore parallel to the generating line of one of the cylinders (40). It follows that, for $h = a^2$, the only surface represented by the primitive equation (4) are the cylinders (40).

3. Chapters on the Mineralogy of Scotland. Chapter VII.

By Dr. Heddle.

In the present chapter Dr. Heddle considers the ores of manganese, iron, chromium, and titanium.

He finds that almost all the manganese in Scotland occurs in the form of an ore of little value—*psilomelane.*

Iron, he has observed in minute laminable specks, in the free or *metallic* condition, at two localities, but sheathed in both cases in magnetite. The quantity was too small for determining the presence or absence of nickel, but he conjectures that these specks may have been minute meteorites, which had fallen into the ocean in which the rock was being formed.

He has found two ores of iron new to Britain,—*turgite* and *martite,*—the one near Oban, the other in Bute.

A series of analyses of *ilmenites* and of *iserines* or "titanic iron sands" are given; and, as a result of a consideration of the modes of occurrence, and of the microscopic features of these minerals, Dr. Heddle concludes that they are specifically distinct; the former being of *chance occurrence* in metamorphosed rocks, while the latter is an almost *invariable constituent* of igneous rocks.

Ilmenite he finds to be very common in Scotland, but to be, for the most part, confined to chloritic and quartzose bands of metamorphic rocks.

He finds that magnetic "black sands" are not unfrequently *chromiferous,* and that to a considerable extent.

4. On the Dimensions of Cast Iron at various Temperatures, with more especial reference to the Phenomena of the Solid floating on the Molten Metal. By W. J. Millar, C.E., Secretary, Inst. Engineers and Shipbuilders in Scotland.

1. In experimenting from time to time on the floating of solid metal on molten metal, the author has observed various phenomena, of which the present paper is descriptive, and this more especially with regard to cast iron and the well-known property of the solid

floating on the molten iron as frequently witnessed in foundry ladles.

Some years ago the author made a number of experiments with pieces of cast iron of different shapes and sizes, which were placed on the surface of a large ladleful of molten cast iron, the results obtained being as follows:—

Several pieces of pig iron were first tried; these at first sank and a rush of hot metal took place upwards, but after a few seconds they rose to the surface, and floated *with very little of their bulk* above the molten metal.

A piece of flattish irregularly-shaped cast iron floated with a small portion only of one of its corners appearing above the surface. Pieces of flat cast iron test-bars were carefully placed on the surface (the latter being well skimmed), these floated *without going below the surface.* One of the test-bar pieces, which was put in end on, kept in this position for a few seconds with its end above the surface, the other end then came up and the piece floated on its flat side.

In another experiment, a cast iron ball, about three inches in diameter, was lowered by means of a wire on the molten surface; the ball at first disappeared, but in a few seconds rose and floated with a small portion of its surface exposed. On being raised out of the molten metal it showed a red glow on the lower part, and when again lowered it did not sink, but floated with a larger portion above the surface than before.

Some pieces of steel rails were put into a Siemens steel-making furnace filled with molten metal; these pieces at first disappeared, but afterwards rose to the surface. Some other pieces, *heated red-hot,* were now put in; these floated without sinking, and showed a little of their bulk above the surface.

2. Different views are held as to the behaviour of cast iron when passing from the molten to the hot solid state, and finally thereafter to the cold (or ordinary temperature) state.

Some hold that the molten metal on solidifying expands, as water does when passing into ice, and that it retains this expansion to such an extent that the cold solid is specifically lighter than the liquid metal. Others hold that no such expansion takes place, but that through cooling the cooled solid becomes specifically heavier than the molten metal. A third view is that the molten metal on solidifying *expands*, and that it thereafter contracts during cooling until it reaches the ordinary atmospheric temperature, and that in this condition it is specifically *heavier* than in the molten state. In reference to these views it may be remarked that the phenomena of freezing of water and of the solidifying of molten cast iron are not quite suitable for comparison, as the ice formed by the solidification of the water remains at the same temperature; the iron, on the other hand, changes in temperature after solidification, cooling gradually until the temperature of the surrounding air is reached.

It is sometimes argued that the sharpness of the edges of castings from iron and some other metals is due to the assumed expansion on setting, but as this sharpness appears in practice to be attainable by hot run metal, whilst dull run metal gives blunt or rounded edges, it is doubtful how far it can be accepted as proving any change due to expansive action.

Again, it is evident from foundry practice that, so far as the volume of the finally cooled solid and the volume when molten is concerned, that an allowance of about $\frac{1}{96}$th part (varying somewhat with the size and shape of casting) has to be made in patterns as representing the lineal contraction during such cooling, and that in consequence we must conclude that the cold solid is specifically *heavier* than the molten metal. Under these circumstances we naturally ask why should the solid metal float in metal specifically lighter than itself? It is obvious to any one who has made such experiments that the floating of the solid iron cannot be due to any supposed phenomena of expansion at setting, as the piece would require to be heated up to the white hot condition or critical point at which it would just begin to melt. And it is found when the floating pieces are taken out and broken through, they only in some cases—depending on their size—show a dull redness.

3. From the author's experiments already mentioned, and from others since carried out and to be summarised, it appears that the *bulky pieces sink at first*, reappearing at the surface in longer or shorter times according to their weight and form, and that small pieces either disappear for only a short time, or remain floating on the surface. Indeed, small flat shaped pieces are unsuitable for these experiments, as the constantly forming skin on the molten

surface interferes with their movement, larger pieces, especially those of a ball shape having a maximum of weight with a minimum of surface, being to be preferred.

The conclusions drawn by the author from his experiments were, therefore, that when the cold solid comes in contact with the intensely heated molten metal, sufficient expansion is induced in the solid metal as to give it the required buoyancy to rise to the surface, and that this may occur by part of the surrounding heat being converted into mechanical work, causing a sudden increase in bulk, and partly by a dilatation due to rise of temperature of the solid. Indeed, it also appears likely that the high temperature surrounding the immersed solid (over 2000° F.) may suddenly cause a change in the condition of the particles of the solid which have most probably taken a strained condition during cooling.

That some such condition exists in castings appears probable, as in some cases annealing has to be resorted to, to prevent liability to fracture. And from experiments made by the author on the deflection and set of cast iron test-bars,* it would appear that when such bars are at first loaded and allowed to deflect, a certain amount of set is observed. On further application of the same, or even of greater loads, this set decreases, until ultimately no set is apparent, showing that in all probability the work done by the load upon the bar, has up to this point been one of freeing the particles from a local strained condition due to cooling. The common foundry practice of hammering curved castings on the concave side so as to straighten them, also points to relief of strain in the particles by the vibration set up. Such a strained condition may very well exist even in so simple and regular a form of casting as a test-bar, as the outer surfaces, cooling more rapidly than the inner, must cause compression of the latter.

4. If we take, as in common foundry practice, $\frac{1}{96}$th part (or $\frac{1}{8}$ of an inch to the foot) as the change in linear dimensions from the molten to the finally cooled solid condition, we may calculate from coefficients of expansion the temperature to which the cold solid would require to be raised to enable it to float on the molten metal. Thus, if we take the rate of expansion per 180° as $\frac{1}{900}$th part

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* *Trans. Inst. Engineers and Shipbuilders in Scotland*, vols. xix. and xxi. *Minutes of Proc. Inst. C.E.*, vol. lviii. part iv.

linear,* we would require a temperature of about 1700°, which would be a bright red heat at least, before the piece would have sufficient increase of bulk to enable it to float. Now, from various experiments made by the author, it appears that many of the pieces which float show little or no redness when taken out, hence some other action seemed necessary to account for the buoyant tendency. Believing, however, that a large part of the heat might disappear as work of expansion, the author has carried out recently a large number of experiments with pieces of cast iron of various sizes and forms. These were carefully callipered before immersion, and as soon as possible after being taken out of the liquid metal in which they had floated (a few seconds in general was all that was necessary for their reappearance), and it was found in every case that a large expansion had taken place, such expansion being about $\frac{1}{100}$th part at least of linear measurement. Here, therefore, we have a sufficient change of bulk to account for the floating phenomena. And this is the more remarkable, as although the change in dimension is equal to the shrinkage in cooling from the molten to the cooled solid state, yet the temperature is very much below the melting-point, as in some cases the pieces were barely red, and would hardly melt lead.

5. Some of the experiments may be enumerated :—

(1) A piece of a test-bar 2 inches broad by 1 inch thick, and filed down exactly to 12 inches long, was placed in a ladle, floated, and was taken out within half a minute; it just showed redness, and it was now found to be fully $\frac{1}{8}$ of an inch longer than at first. It was callipered from time to time as it cooled, showing a decrease in length. Finally cooled in water, and now being just warm to the touch, was found to be nearly down to 12 inches; when quite cold came back to the 12 inches.

(2) A cutting from an 11-inch pipe was carefully callipered when cold, and found to be exactly 11 inches inside measurement, and outside $12\frac{7}{8}$ inches; it was placed in a ladle holding 3 tons, disappeared for about twelve seconds, came up to surface and was immediately lifted out, was again callipered and found to measure inside $11\frac{1}{8}$ inches, outside 13 inches, and this after it had become quite dark;

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* Prof. Rankine, *Manual of Civil Engineering.*

no red visible, as a little time was taken getting any adhering metal knocked off.

(3) A piece of pig iron 8½ inches long floated in about six seconds, and appeared to have gained about $\frac{1}{16}$ of an inch in length.

(4) A piece of test-bar 2 in. × 1 in. × 9 in. floated in about four seconds; showed from $\frac{1}{16}$ in. to $\frac{3}{32}$ in. increase in length, and was a dull red; broken through, and a piece of lead laid upon the surface, the lead did not melt, but did so afterwards when pressed between the two broken parts of the bar. As lead melts about 630° F., the temperature of the iron could not have been much above this.

(5) A piece of a casting 18¼ inches long and of triangular section was found to measure 18$\frac{7}{16}$ inches after floating, equal to $\frac{3}{16}$ of an inch of increase, was dull red; afterwards, when quite black, had $\frac{1}{16}$ in. to $\frac{3}{32}$ in. of expansion. A piece of lead laid upon it did not melt for some time.

(6) Another piece of a test-bar 2 in. × 1 in. × 12 in. was tried; after floating, it was taken out and found to measure 12⅛ inches; here again an increase of ⅛ of an inch was obtained, and the bar was barely a dull red. This piece was again put in ladle, floated easily, and was taken out somewhat red, callipered, and found to be 12⅛ inches in length.*

(7) Other experiments have been made, but sufficient instances have been given to prove the large increase of bulk which so rapidly takes place in all these floating pieces of cast iron. The author therefore believes that the *cause of the floatation* is in the *increased bulk* thus obtained, which from its extent is quite sufficient in itself to explain the phenomena satisfactorily, as it will be observed that the increments found to exist were practically equal to the decrement which occurs from the molten to the finally cooled state, and that, therefore, the floating pieces had become of equal bulk to an equal weight of the liquid metal. It may be mentioned that great care was taken to get the real surface of the pieces after being taken out of the ladles, and in some cases the parts to be measured were oiled or coated with blacking to keep the surface free of scum or loose metal.

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* From measuring the pattern of these test-bars and the test-bars themselves there appears a difference of ⅜ of an inch in a length of 42 inches, showing a shrinkage of rather *less* than ⅛ of an inch to the foot.

(8) With the view of ascertaining the rate of increase due to rise of temperature, some experiments were made by heating pieces of test-bars in a smith's fire, and noting the extension according to the time.

These experiments pointed out that the increase of size is at first rapid, and thereafter comparatively slow; thus a piece of test-bar, 2 in. × 1 in. × 13 in., had two centre points marked upon it exactly 12 inches apart; it was placed in a smith's fire and heated for about a minute, when it was found to have gained about $\frac{1}{16}$ of an inch; would not melt lead. Again heated for about same time, and found to have about $\frac{3}{32}$ of an inch of an increase; still black, and did not melt lead; heated again, and now found to have its original length increased by $\frac{1}{8}$ of an inch, it was now a dull red and melted lead, heated once more for two minutes, and now a bright red; but the increase, very little if any over the $\frac{1}{8}$ of an inch; heated again, and taken out white hot, when it broke in two pieces. Another piece, same size, was tried by heating it up to a white heat at once, time about four minutes. The expansion was nearly $\frac{3}{16}$ of an inch; put in fire again, and taken out very white hot showed about $\frac{3}{16}$ of an inch of increase in the 12 inches. Allowed to cool gradually, and in seven minutes it measured $12\frac{1}{8}$ inches; it was now quite dark, and melted lead when the latter was rubbed on the bar.

These experiments quite corroborate the floating metal experiments so far as the rate of increase in size goes, viz., that at first, and even at a comparatively low temperature, there is a large increase, and that thereafter the increase is much less in proportion to the greatly increased temperature even at white heat.

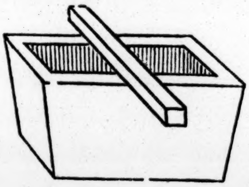
The author, therefore, thinks that both experiments prove that a large part of the first applied heat disappears in work of extension, the later applied heat showing more distinctly rise of temperature and change of condition of the metal towards melting.

(9) Some experiments were carried out to determine the question of expansion of cast iron on setting; the results of these are, however, not favourable to such an action, as no special movement could be detected. And, indeed, all the practical men whom the author has consulted, agree in stating that they have not observed

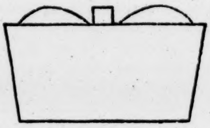
any such action in their experience. Movements of the liquid metal, after pouring, have been occasionally noticed, but these are accounted for by movements of cores or air; the necessity for immediately freeing the metal from the cores on setting, is pointed out as against any such supposed expansion, as the tendency is rather to shrink and tighten up against the inner part or core.

One experiment which the author has recently made may be noted as pointing out the great difficulty in dealing with this subject, so as to get rid of disturbing causes such as air or gas entangled in the metal.

The metal was run into a mould 8 in. × 5 in. × 4 in., and a wrought iron bar about 18 in. × 1 in. × 1 in. was laid across thus—



and the metal brought to about touching the bar; after about a minute a thin moulder's trowel could be almost passed between the bar and the still molten metal. After setting, the trowel could hardly be put in as before, and the metal thereafter began to rise up on each side of the bar thus—



The metal had now assumed an orange colour, the part below the bar being brightest. On examining the metal when cold it was found that the space or difference between the high and low parts was $\frac{1}{8}$ of an inch. A few air holes being observed on the top of the casting, the metal was cut through at the raised and flat parts, when it was found that some honeycombing existed, due apparently to air bubbles.

In some other experiments made, this uprise was not observed, and it appears probable that the uprise of the surface of the metal, as above described, was due to the pressure of air or gas, which by compression due to *shrinkage* was forced upwards, no other means of escape being possible. The upward force must necessarily have been slight, as it was insufficient to raise the bar lying on surface and weighing about 5 lbs. This view the author finds borne out by the manager of the foundry where this experiment was made, as he states that he has noticed the same action at times, but only *where air was present*, such as when draughts of air played over the surface at casting. The presence of air or gas also accounts for movements which have at times been observed to take place in the hemispherical moulds used for casting balls, as the author has been informed by moulders accustomed to this work, that sufficient opening of the two halves of the mould is noticeable to show the hot solid metal within, but that this is due to air or gases entangled in the casting.

(10) From some experiments made by the author with other metals, it appears that when the solid pieces float that their bulk is also increased as in the case of cast iron. Thus, when a piece of gun metal was placed in a crucible of molten gun metal it sank, but shortly reappeared; on being taken out it was found that it had increased in length by $\frac{1}{50}$th part, whilst the shrinkage allowed for such an alloy would be even rather less than that.

Phosphor bronze also floated in molten phosphor bronze after sinking, behaving like the cast iron and gun metal. Type metal gave doubtful results with light pieces, heavy pieces going to the bottom of ladle and remaining there till melted. Lead, when tried also with large pieces, sank to the bottom, where the piece could be felt remaining there till melted; and incidentally it may be mentioned that when very large pieces of cast iron are used these remain so long at bottom of ladle as to have their ends melted off before rising to surface.

5. On an Oxycyanide, and a New Oxide, of Bismuth. By M. M. Pattison Muir, M.A., Fellow, and Prælector in Chemistry, of Gonville and Caius College, Cambridge.

1. Bœdeker (*Annalen*, 123, 61), by the action of potassium cyanide on bismuth nitrate, obtained a reddish-brown salt, to which he assigned the formula $Bi_2O_5.2H_2O$. In an examination of the oxides

of bismuth in conjunction with Hoffmeister and Robbs (*Chem. Soc. Jour.*, 1881; *Proc.*, p. 21), I had occasion to prepare Bœdeker's salt; a slight study of its properties proved it to be a compound of no little interest. When a concentrated aqueous solution of potassium cyanide is added to a solution of metallic bismuth in excess of nitric acid, and the mixture is boiled, a brownish-red solid and a more or less dark red liquid are obtained, and quantities of hydrocyanic acid are evolved. When the excess of nitric acid is nearly neutralised by potash before addition of potassium cyanide, the colour of the solid is a much lighter brown, and the supernatant liquid is nearly or quite colourless. When a large excess of nitric acid is present, no solid, but only a red liquid, is produced. After very many trials, this method of preparation was abandoned, and potassium cyanide solution was added to a solution of crystallised bismuth nitrate, in the minimum quantity of dilute nitric acid: much more constant results were thus obtained. Various preparations of the puce-coloured salt were made, using varying quantities of bismuth nitrate and potassium cyanide; in each case the puce-coloured precipitate was washed with boiling water until the washings were free from cyanogen and from potassium; in one or two instances the precipitate was also boiled with extremely dilute sulphuric acid (about 1 : 300), and again washed free from acid. The temperatures at which the various preparations were dried are noted in the following table.

Inasmuch as Bœdeker states that he failed to obtain evidence of cyanogen in the new salt described by him, and as an examination for cyanogen by the ordinary tests confirmed this result, I was convinced that the salt must be an oxide of bismuth.

Bismuth was determined by heating over a Bunsen lamp, whereby the salt was decomposed with production of bismuthous oxide; the loss of weight (of the dehydrated salt) gave, as I supposed, the amount of oxygen in excess of that required to form Bi_2O_3. Water was determined by heating in a current of dry air, and determining the increase of weight of a calcium chloride tube attached to the apparatus in which the salt was heated.

2. The following table contains the analytical results obtained:—

No.	Mode of Preparation.	Temp. at which Salt was Dried.	Percentages of Bismuth Found.	Mean Percentage of Bismuth.	Mean Percentage of Loss on Ignition, regarded as Oxygen.
I.	By addition of KCN to Bi in excess of HNO_3.* . .	150°	78·53; 82·21	80·37	19·63
II.	By addition of KCN to $Bi3NO_3$ in nitric acid (exact proportions not noted), . .	150°	79·33; 80·29	79·81	20·19
III.	Do. do.† KCy : $Bi3NO_3$= 1:1, . . .	150°	81·04	81·04	18·96
IV.	Do. do. KCy : $Bi3NO_3$= 3:1, . . .	150°	79·93; 79·88; 78·97; 80·49.	79·82	20·18
V.	Do. do. KCy : $Bi3NO_3$= 3·5 : 1, . .	100°	78·07; 78·09; 78·62; 78·86; water in this salt=1·5 per cent.	79·72‡	20·28
VI.	Same salt as No. V. dried at . .	150°	79·08; 79·31	79·19	20·81
VII.	Do. do. KCy : $Bi3NO_3$= 2·5 : 1, . .	100°	75·07; 75·69; 75·85; water in this salt = 2·1 per cent.	77·15‡	22·85
VIII.	Do. do. KCy : $Bi3NO_3$= 2·5 : 1, . .	150°	76·39; 76·69; 77·31; 77·80; 77·83	77·20	22·80
IX.	Addition of KCN (excess) to Bi_2O_3 in slight excess of HCl, . . .	150°	79·45	79·45	20·55

	Mean of Means.	Calculated for Bi_2O_7.
Bismuth	= 78·86	78·95
Oxygen	= 21·38	21·05
Oxygen in excess over Bi_2O_3	= 12·40	12·03
Bi_2O_3: excess of O .	=117:16·2	117:16

3. These results seemed altogether to confirm the view that the salt to which Bœdeker had given the formula $Bi_2O_5.2H_2O$ contained,

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* Many other preparations made by this method were analysed, but the results varied considerably; the above is given only as a specimen.

† This salt was considerably lighter in colour than the others.

‡ Calculated on the *dry* salt.

when dried at 150°, bismuth and oxygen only, and these in the atomic proportion Bi_2O_7.

But I subsequently found that the supposed oxide, when heated in a closed tube, evolved a little ammonia. I also proved the presence of nitrogen by the sodium test. Determinations were therefore made of nitrogen and of carbon, the former by burning with soda lime, the latter by burning with copper oxide.

1. 0·7075 grm. gave 0·0285 grm. N. =4·03 per cent.=7·49 per cent. cyanogen.
2. 0·867 " " 0·0365 " N. =4·20 " =7·80 " "
3. 1·113 " " 0·046 " N. =4·14 " =7·69 " "
4. 0·8275 " " 0·1275 " CO_2=0·0348 grm. C=0·0754 grm. CN=9·10 per cent. cyanogen.
5. 1·2435 " " 0·145 " CO_2=0·040 " C=0·0866 " CN=7·00 " "

Determinations of water made simultaneously with those of carbon gave 4·60 and 4·75 per cent.

Hence mean percentage of cyanogen = 7·81
Do. do. of water = 4·67

The preparation used in these analyses contained 77·25 per cent. bismuth. The mean percentage of bismuth, calculated from analyses of those preparations which were dried at 120° and contained a little water, is 76·80 per cent.; taking this number and 4·67 as representing the amount of water in the salt, and determining oxygen by difference, the results agree very well with the complex formula $4Bi(CN)_3.5Bi_2O_5.10H_2O$. The analytical numbers agree fairly well with the formula $2Bi(CN)_5.5Bi_2O_5.9H_2O$, which requires bismuth 75·40, cyanogen 7·78, oxygen 11·98, and water 4·85 per cent.

	Found.	Calculated for $4Bi(CN)_3.5Bi_2O_5.10H_2O$.
Bismuth, . . .	76·80	76·72
Cyanogen, . . .	7·81	8·15
Oxygen (by difference),	10·72	10·44
Water, . . .	4·67	4·69
	100·00	100·00

Calculating all the results on the dry salt, numbers are obtained which agree better with the formula $Bi_7(CN)_6O_{15}$ than with any other.

	Found.	Calculated.
Bismuth, . . .	78·86	78·78
Cyanogen, . . .	8·14	8·37
Oxygen (by difference),	13·00	12·85
	100·00	100·00

The numbers agree also very well with the formula $2Bi(CN)_5$ $5Bi_2O_5$, which requires bismuth 79·24, cyanogen 8·18, and oxygen 12·58 per cent. Various other formulæ may be found, agreeing more or less closely with the analytical results, but in each the atomic proportion of oxygen to bismuth, in excess of that required to form $Bi(CN)_3$ or $Bi(CN)_5$, must be expressed by a formula Bi_2O_x where x is not less than 5; in other words the action of potassium cyanide has been an oxidising action, while at the same time producing a cyanogen compound.

4. Unless a considerable excess of potassium cyanide is added, but little of the new salt is produced. If the liquid be so nearly neutral before adding cyanide that one drop of moderately strong potash solution produces a permanent precipitate, the precipitate produced by the cyanide consists of nearly pure Bi_2O_3, with small quantities of the new salt. If there be rather more free nitric acid than this, the precipitate produced by the cyanide is rich in an oxide of bismuth to be described in the sequel, viz., Bi_4O_7 (see par. 5).

In one instance one part of potassium cyanide was added to one part of bismuth nitrate, dissolved in the minimum quantity of dilute nitric acid, a portion of the liquid was boiled for three or four minutes, and another portion for twenty-five minutes. The precipitate produced in the latter liquid was darker in colour than that in the former, and contained rather less bismuth; the lighter coloured salt contained 81·59 per cent. bismuth, the darker salt gave bismuth = 80·89 per cent.

When from 2 to 2·5 parts potassium cyanide are used for each part bismuth nitrate in solution, and the liquid is boiled, the precipitate very quickly becomes of a uniform puce-red colour, while the supernatant liquid is reddish-brown. The best results are, I think, obtained with this proportion between cyanide and bismuth nitrate.

When the cyanide solution is added to a cold solution of bismuth nitrate, an almost colourless salt is thrown down, which becomes puce-red on boiling; this colourless salt is perfectly free from cyanogen, and appears to be bismuthous oxide. If, however, anhydrous bismuthous oxide be boiled with potassium cyanide solution,* no change occurs, nor does addition of potash induce any reaction. Although the liquid, after addition of the cyanide, is markedly alkaline, nevertheless the presence of free acid in the bismuth solution is necessary; that this acid need not be nitric acid was shown by adding potassium cyanide to solution of bismuthous oxide in slight excess of hydrochloric and sulphuric acids respectively; in each case the puce-red salt was obtained on boiling.

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* This has been confirmed by repeated trials, and by analysis.

It is, I think, evident, that to ensure production of the new salt, rapid chemical change—partly oxidation, partly formation of bismuth cyanide—must occur; neither bismuthous oxide nor any other salt must be allowed to get permanently produced, the whole system must not settle down into stable equilibrium until it is forced to assume that configuration of which the complex oxycyanide is a component part.

5. *Bismuth Oxycyanide*—probably $2Bi(CN)_5.5Bi_2O_5$—when dried at 140°–150° is a reddish-brown solid, somewhat similar in appearance to lead dioxide, but showing a more decided puce colour than that salt. It begins to undergo change at about 200°, but the loss of weight at that temperature is small; about half a gram of the salt lost 3·50 per cent. at 210°, and 7·50 per cent. at 350° (the oxycyanide in changing to Bi_2O_3 loses about 12 per cent.). When a large quantity of the salt is heated in a crucible, a considerable amount of metallic bismuth is produced; but when quantities of from 0·5 to 1·0 grams are so heated the residue consists only of bismuthous oxide.

The oxycyanide scarcely takes up water when exposed to ordinary or to moist air; thus about half a gram increased only 1·80 per cent. in weight after 144 hours' exposure over water. It does not suffer change when covered with water and exposed to the action of sunshine.

Bismuth oxycyanide is dissolved by hot concentrated nitric or sulphuric acid, with production of dark-red liquids, from which water causes precipitation of red substances containing bismuth, and soluble in hot potash solution. Hydrochloric acid dissolves the oxycyanide more slowly, a portion remaining undissolved even after continued action. When heated with a *slight* excess of potash these liquids yield reddish precipitates, which are mostly soluble in hot concentrated potash solution, and when any of these deep red acid solutions is boiled it is *very slowly* decomposed with ultimate production of bismuthous nitrate, sulphate, or chloride. When sulphuric acid is employed as solvent, the salt which separates after concentration is probably $BiHSO_4.3H_2O$ (47·9 per cent. bismuth was obtained instead of 45·95 per cent. required by this formula). The specific gravity of bismuth oxycyanide at 20° is 4·64 referred to water at the same temperature (mean of 4·67 and 4·61; weighings done in benzene, specific gravity at 20° = 0·8804).

6. Bismuth oxycyanide is readily acted on by hot, and more slowly by cold, concentrated aqueous potash, with production of a very deep red liquid. So far as I have examined this action, about 75 per cent. of the oxycyanide is invariably converted into the oxide Bi_4O_7, while 25 per cent. goes into solution. This change appears to be independent of the quantity of potash, provided there be excess, and of the time of action of the hot liquid on the oxycyanide.

When the strongly alkaline red liquid is neutralised, preferably by hydrochloric acid, a reddish-brown flocculent precipitate is formed, which, after washing with hot water, contains the whole of the bismuth originally in solution, but is free from potassium. When the precipitate has been dried at 100°, it appears as a nearly black hard cystalline substance resembling magnetic oxide of iron, and is now only dissolved by long-continued boiling in strong acids, with formation of deep red liquids, which are scarcely decomposed except by evaporation to dryness. This salt is strongly decomposed when heated to redness in air, with production of bismuthous oxide; heated in a limited supply of air a portion remains as metallic bismuth; the salt contains a considerable quantity of water; it is unchanged, otherwise than that it loses water, at 300°. It may be readily dissolved and decomposed by treatment with bromine and aqueous potash.

I have made many analyses of this peculiar substance, but the results show great variations; inasmuch, however, as the preparation of this substance in quantity involves the use of much potassium cyanide, which is an extremely disagreeable reagent to work with, especially when added to hot acid liquids, and the expenditure of a great deal of time, I think it may be well to put on record a synopsis of the results obtained.

No.	Preparation.	Temp. at which Dried.	Percentage of Bismuth.		Total Loss when Heated over Blowpipe. Per cent.	Percentage of Water; determined by Heating in Dry Air with $CaCl_2$ Tube attached.
			By Precipitation as Carbonate.	By Ignition in Air, and weighing Residue as Oxide.		
I.	Made in earlier part of investigation, . .	150°	23·7; 21·0	24·0	73·4	...
II.	Made at later part of investigation, . .	300°	25·5; 27·5	...	...	...
III.	Made from same oxycyanide as No. II.,	300°	...	7·08; 6·70; 7·17; 7·77	92·1; 91·4; 92·0; 91·8	18·75; 28·28; 26·10; 31·0; 20·0
IV.	Made from same oxycyanide as No. II.,	300°	...	...	...	16·9
V.	Made from another preparation of oxycyanide, . . .	300°	...	6·7	...	17·5
VI.	From another preparation of oxycyanide,	250°	Burned with soda lime, gave 36·34 per cent. N. = 67·47 per cent. CN.			
VII.	From another preparation of oxycyanide,	250°	Burned with soda lime, gave 36·32 per cent. N. = 67·45 per cent. CN. Burned with CuO, gave 15·80 per cent. C. = 34·23 per cent. CN.			

From the three last determinations I conclude that the salt probably contains a considerable quantity of nitrogen, in addition to a large percentage of cyanogen. The variations in the quantities of bismuth found are remarkable; to attempt the construction of a formula from these results would be useless.

7. It has been already stated, that under certain conditions (see par. 4) the precipitate formed by the action of aqueous potassium cyanide on bismuth nitrate contains considerable quantities of the oxide Bi_4O_7; also that the same oxide is produced by the action of hot concentrated aqueous potash on bismuth oxycyanide; the formation of this oxide in the first of these reactions is almost certainly to be traced to a secondary change proceeding after the production of the oxycyanide.

Various preparations of the new oxide were made; when thoroughly washed with hot water the salt contains no potassium, it is very difficult to remove every trace of cyanogen; after the analyses detailed in the following table had been made, it was found that the various preparations when mixed contained about 0·25 per cent. cyanogen (mean of three determinations—two of nitrogen, and one of carbon). The salt after drying at 100° is anhydrous. The analytical results are collected in the following table:—

No.	Mode of Preparation.	Temp. at which Salt was Dried.	Percentage of Bismuth Found.	Mean Percentage of Bismuth.	Mean Percentage of Oxygen.	Mean Percentage of Oxygen in excess of that to form Bi_2O_3.	Proportion of Bi_2O_3 : excess of O.
I.	Addition of KCN to Bi in HNO_3, and boiling precipitate in concentrated KOH, . . .	100°	88·59; 89·05	88·82	11·16	0·91	117; 1·1
II.	Similar to No. I., but precipitate by KCN boiled with very dilute H_2SO_4 before treatment with KOH, . .	100°	88·34; 88·73	88·53	11·47	1·22	117; 1·5
III.	KCN to $Bi3NO_3$ in dilute HNO_3, and subsequent boiling precipitate with KOH	100°	88·43	88·43	11·57	1·32	117; 1·6
IV.	Nos. I., II., and III. mixed, again boiled with KOH, &c., .	160°	88·59; 88·72; 88·81; 88·90;	88·75	11·25	1·00	117; 1·3

	Mean of Means.	Calculated for Bi_4O_7.
Bismuth . . . . . =	88·64	88·24
Oxygen . . . . . =	11·36	11·76
Oxygen in excess over Bi_2O_3 =	1·11	1·65
Bi_2O_3: excess of O . . =	117; 1·4	117; 1·9

The best method of preparing this salt is to boil a solution of bismuth nitrate in the minimum quantity of dilute nitric acid, with three or four times its weight of potassium cyanide dissolved in a little water, to add a considerable excess of potash, and to continue boiling for some time; to pour off the red liquid and boil again with potash as long as the liquid becomes coloured, to wash with hot water till the washings are quite free from alkali, and to dry at about 150°.

This salt is quite unacted on by hot potash.

8. *Bismutho-hypobismuthic oxide* (I think the oxide Bi_4O_7 may be thus named) is a heavy dark grey crystalline salt; the specific gravity varies, according to the method of preparation, from 7·8 to 8·5 (at 20° referred to water at the same temperature, weighings made in benzene), which is higher than that of any other oxide of bismuth. This oxide suffers no loss of weight at 300°; it gives off oxygen at a red heat with production of Bi_2O_3. It undergoes no change either in ordinary or in moist air, nor is it affected when covered with water and exposed to direct sunlight for some days. Strong hot nitric acid readily dissolves this oxide with formation of a purple-red liquid, which is *slowly* decomposed on evaporation. A solution of the salt in strong hydrochloric acid, which solution is also red-coloured, is more quickly decolorised on boiling; hot concentrated sulphuric acid partly dissolves this oxide, forming a brown-red liquid, and partly converts it into an almost colourless salt, which, after being washed free from acid, appeared to be $(BiO)_2SO_4H_2O$ (Bi found = 75·0 per cent.; calculated = 74·21 per cent.). The sulphuric acid solution, on evaporation, yielded colourless crystals which, after drying on a porous tile, contained about 56 per cent. of bismuth ($Bi_2.3SO_4$ requires 59·32 per cent.). I think it very probable that the green oxide of bismuth described by Arppe, (*Pogg.* 64, 237) as produced by the action of boiling nitric acid on (so-called) bismuthic acid, consisted of Bi_4O_7 containing a little undecomposed Bi_2O_5.

6. Mathematical Note. By Mr. T. B. Sprague.

7. On the manner in which Silicon, Phosphorus, Manganese, and other elements exert their influence upon Steel.

By R. Sydney Marsden, D.Sc., F.R.S.E., F.C.S., &c.

(*Abstract*).

This paper is a continuation of the author's previous paper on "The state of carbon in iron and steel, a new hypothesis of the hardening of steel" (read on the 19th December 1881, see p. 368), and is an attempt to give an explanation in accordance with the

views given out in that paper of the manner in which the various elements most common in steel exert their influence in so materially modifying the properties of the metal.

The following are the elements the action of which is considered, viz., silicon, sulphur, phosphorus, manganese, chromium, tungsten, and titanium.

PRIVATE BUSINESS.

Mr. Sang's motion of January 16th, that Law XIV. be amended by the addition of the words, "Excepting when there are five Mondays in January, in which case the meetings shall be held on the third and fifth Mondays of that month," was adopted by the Society, with a verbal emendation. The following words were accordingly added to Law XIV.: "Excepting when there are five Mondays in January, in which case the meetings for that month shall be held on the third and fifth Mondays."

Monday, 6th March 1882.

Professor H. C. FLEEMING JENKIN, F.R.S., Vice-President, in the Chair.

The Chairman intimated that a letter had been received from the Imperial Society of Naturalists of Moscow, inviting the Society to be represented on the 14/2 May 1882, at the celebration of the fiftieth anniversary of the graduation of its Vice-President, Dr. Charles Renard.

The following Communications were read:—

1. The Effect of Flame on the Electric Discharge. By Dr. A. Macfarlane and Mr. D. Rintoul. (Plate IV. *a*).

The properties of flames of various kinds as generating electricity and as serving to conduct a voltaic current, as also their behaviour under the influence of a charge of electricity, have been investigated by several philosophers.* But, so far as we know, the effect of flame on the electric spark has not been methodically observed, or at all events has not been methodically measured. This was the problem which at the opening of the College session presented itself to us, and the results now attained by a course of experimenting appear capable of throwing some light on the solution.

We first made a number of tentative experiments, for the purpose of finding out the general aspect of the phenomena, and the conditions most favourable for exact measurement. An ordinary Bunsen burner served to supply a flame luminous or non-luminous. It was always connected with the earth, and the charged body was in general a disc of 4 inches diameter, connected along with a large Leyden jar to the insulated conductor of a Holtz machine. We tried the disc in a position above the flames, but found that the disturbing conditions introduced were, as was to be expected, rather numerous, namely, the heating of the disc and the covering of it with soot, and the melting of the gutta-percha covering of the connecting wire. Hence for a series of measurements we preferred the disc placed in a position at the side, as represented in the accompanying figures. (See Plate IV. *a*).

The series of observations finally attained are recorded in Tables I. and II.; they are supported by the more preliminary observations. The charged disc was throughout placed at the side of the Bunsen tube in a vertical plane, and so as to have its centre on the same level with the mouth of the tube. The conditions varied were—*first*, the nature of the flame; *second*, the sign of the charge on the disc; *third*, the height of the flame; *fourth*, the distance of the disc from the tube. As regards the first variation two states were observed, the one being the clear flame without any luminosity, the other being the flame as luminous as possible. The height of the flame was varied through a range from 1 cm. to 8 cm., but sometimes the range was extended to the maximum height of the flame (about 20 cm.). In the case of the non-luminous flame, it was the height of the apex of the cone that was measured off; while in the case of the luminous, it was the extreme tip. The total height of the former flame may be taken as double that of the cone. The

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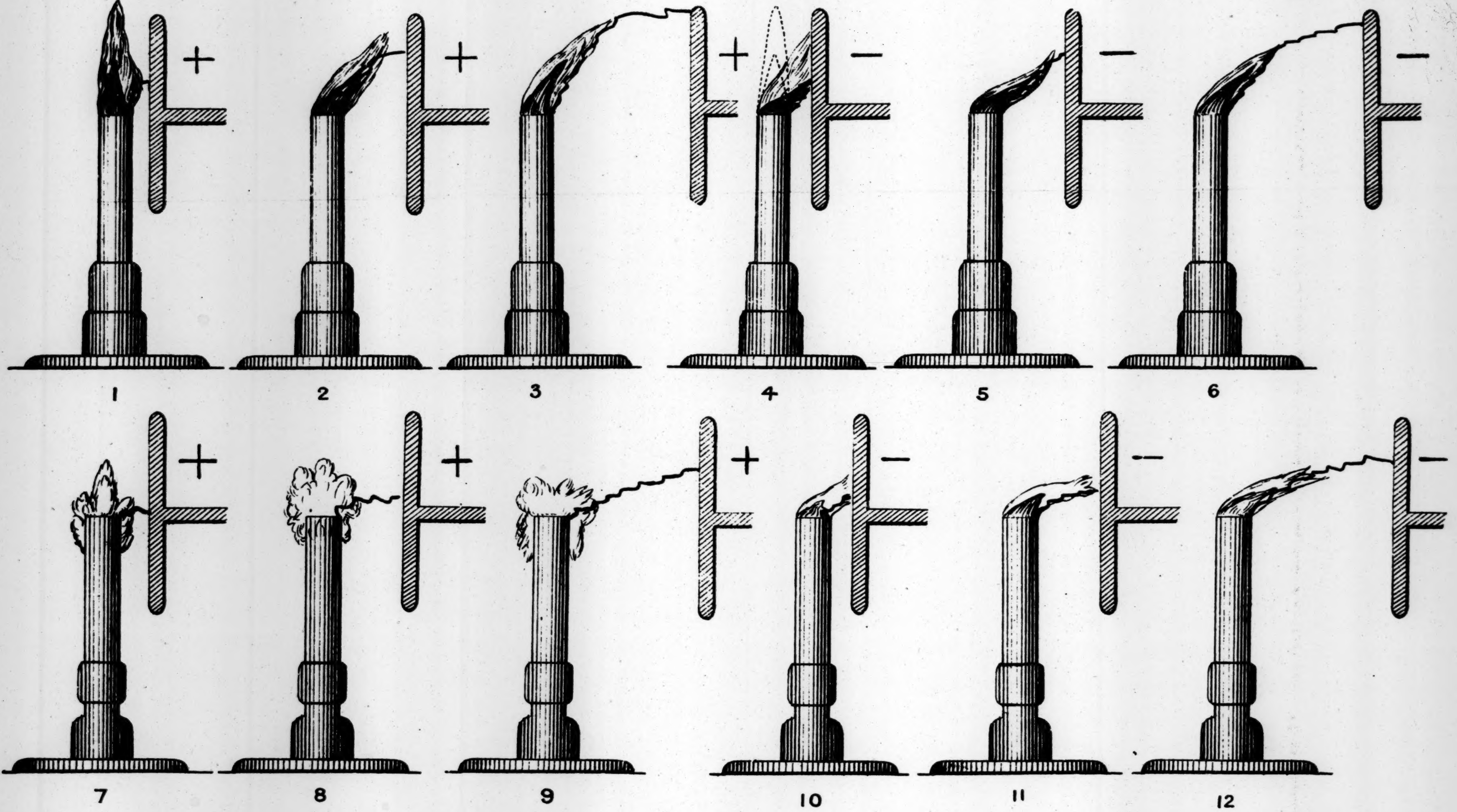
* A summary of what has been done is given in a recent paper by Holtz, *Carl's Repertorium*, vol. xvii. p. 269.



Figs. 1– 3. Flame non-luminous, electricity on disc positive.
Figs. 4– 6. " " " " negative.

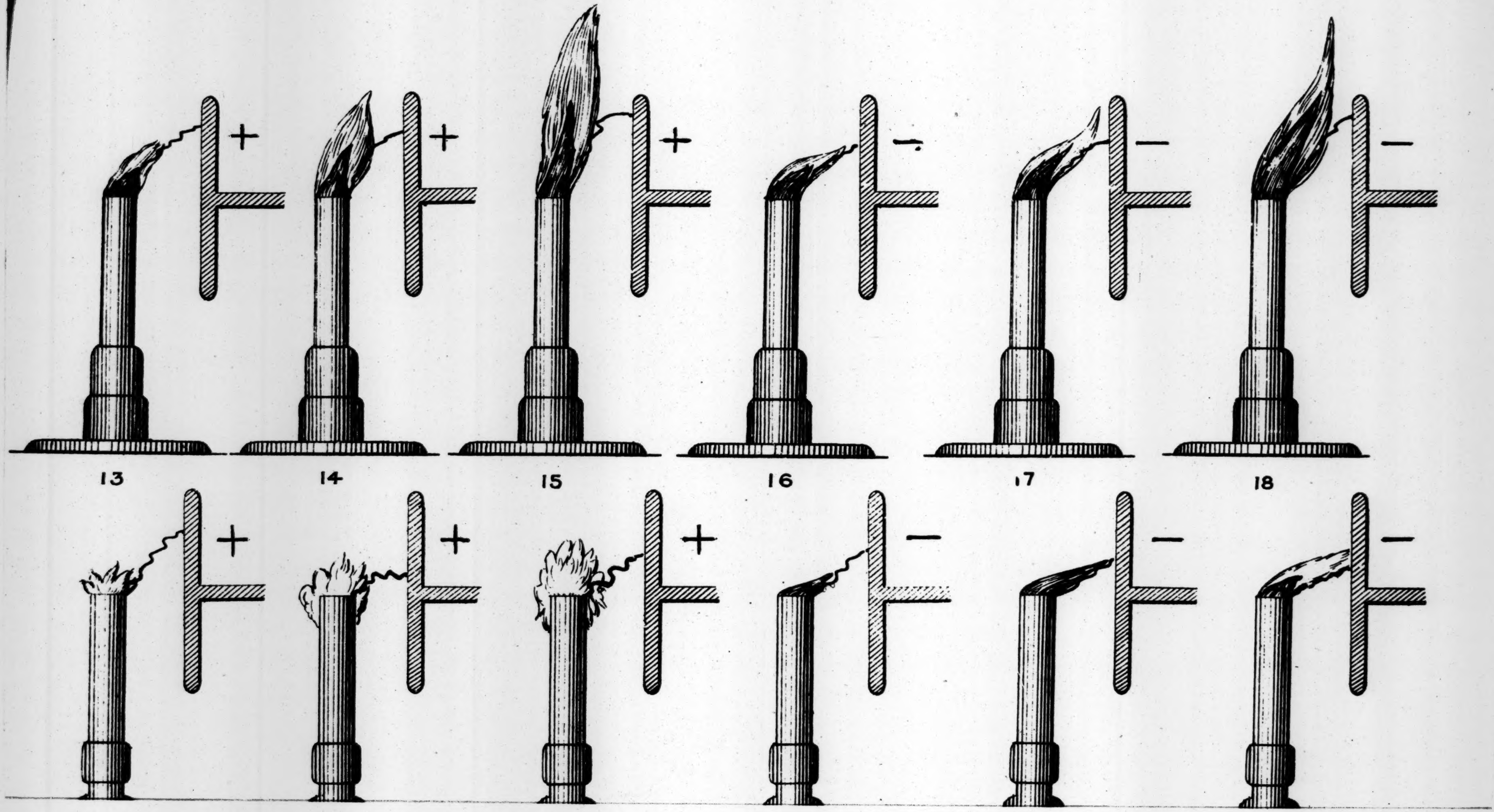
Figs. 7– 9. Flame luminous, electricity on disc positive.
Figs. 10–12. " " " " negative.

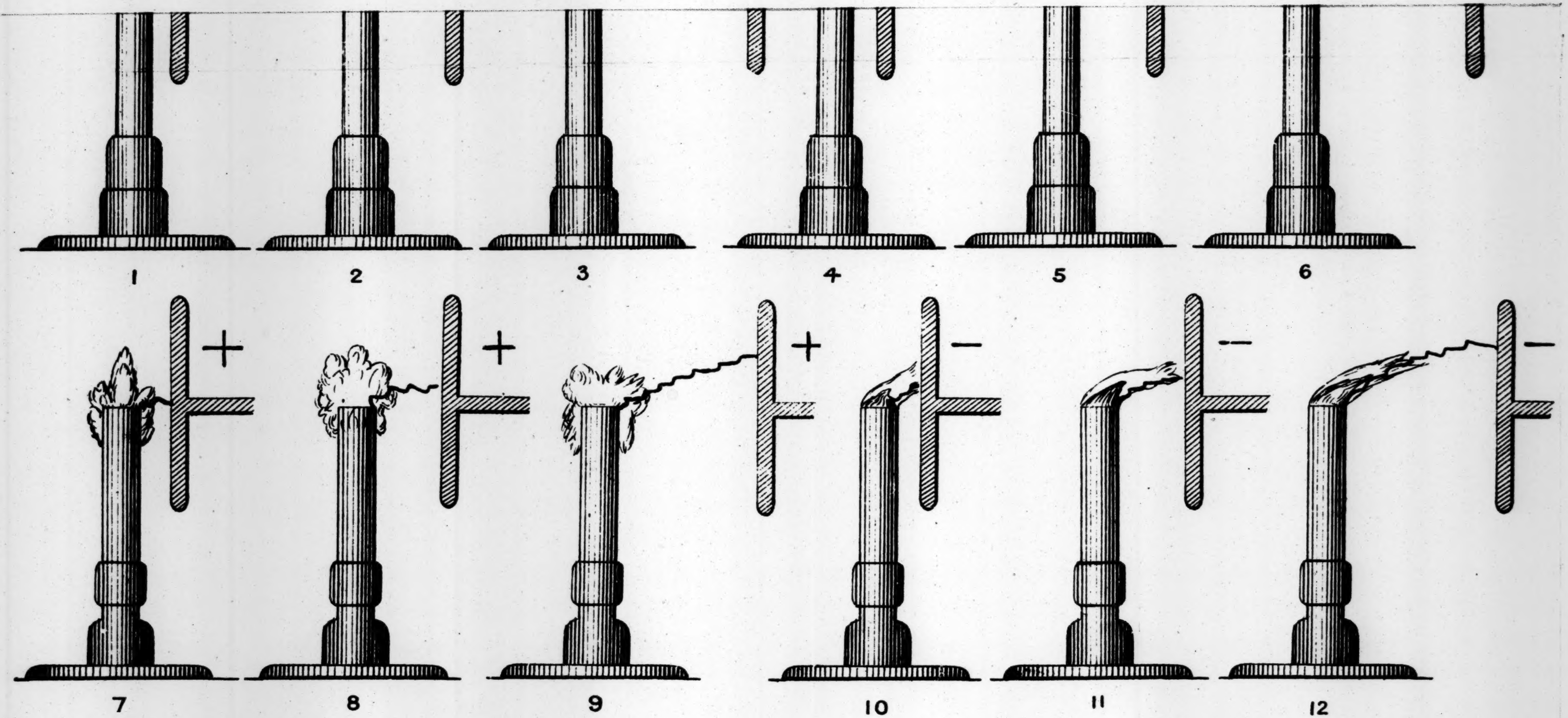
Figs. 1–12. Height of Flame constant.

Figs. 1– 3. Flame non-luminous, electricity on disc positive.
Figs. 4– 6. 〃 〃 〃 〃 negative.

Figs. 7– 9. **Flame** luminous, **electricity on disc** positive.
Figs. 10–12. 〃 〃 〃 〃 negative.

Figs. 1–12. Height of Flame constant.

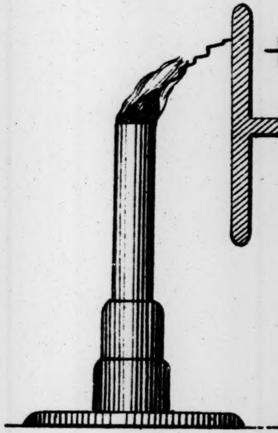




Figs. 1– 3. Flame non-luminous, electricity on disc positive.
Figs. 4– 6. 〃 〃 〃 〃 negative.

Figs. 7– 9. Flame luminous, electricity on disc positive.
Figs. 10–12. 〃 〃 〃 〃 negative.

Figs. 1–12. Height of Flame constant.



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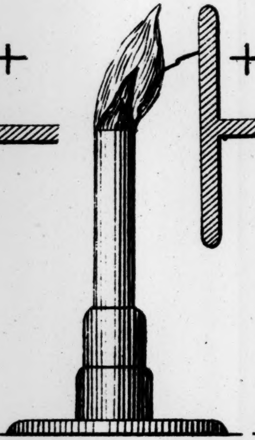

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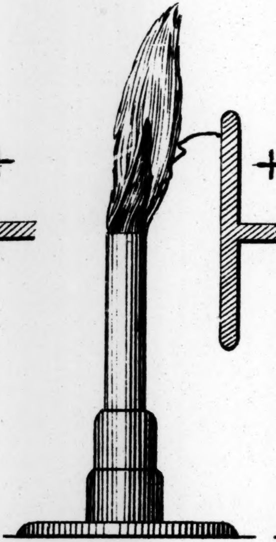

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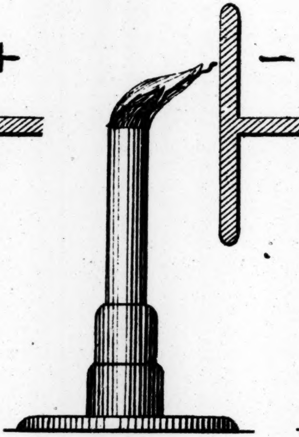

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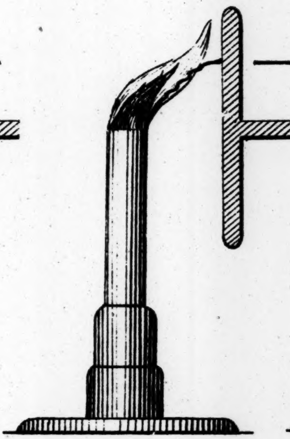

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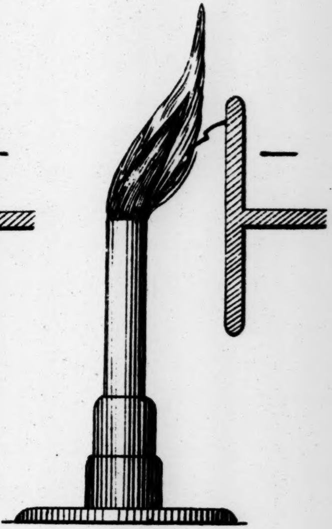

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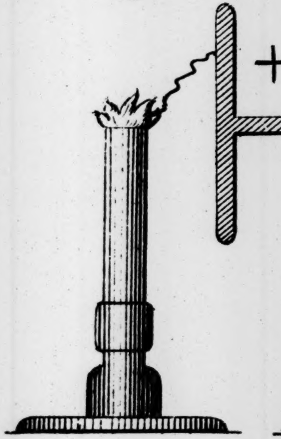

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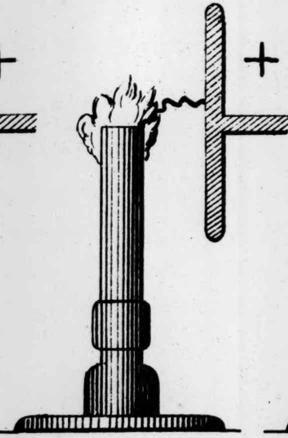

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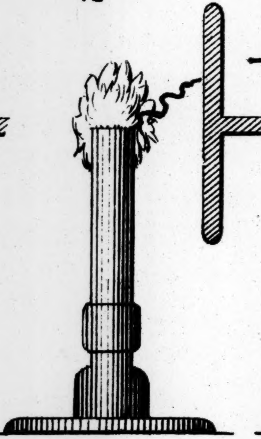

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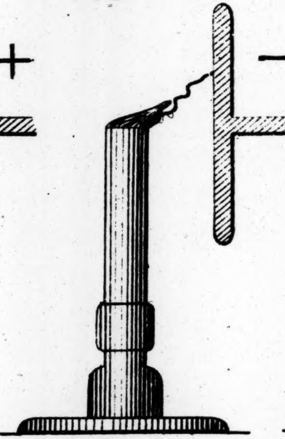

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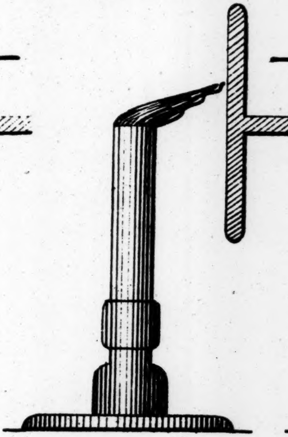

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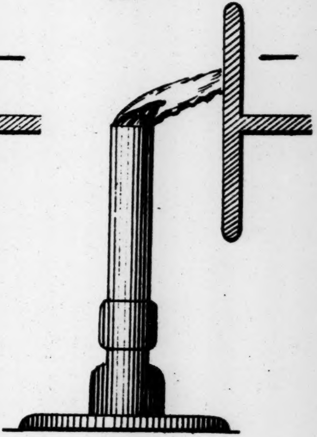

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Figs. 13–15. Flame non-luminous, electricity on disc positive.
Figs. 16–18. " " " " negative.

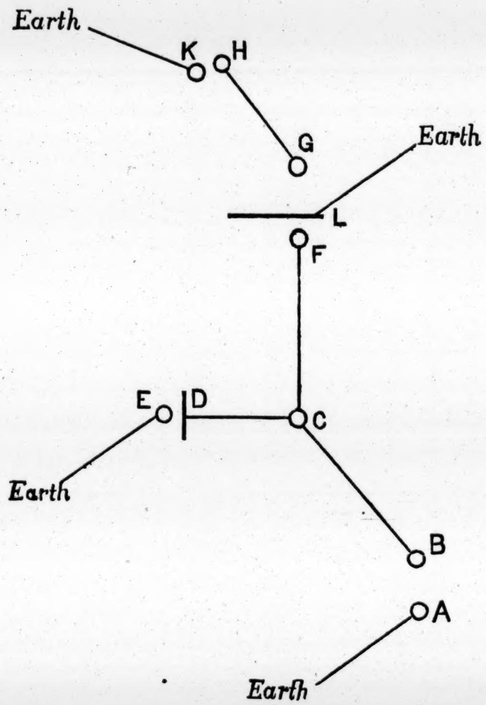
Figs. 19–21. Flame luminous, electricity on disc positive.
Figs. 22–24. " " " " negative.

Figs. 13–24. Distance of tube from disc constant.

J. Bartholomew, Edinʳ.

distance of the tube was varied through a range extending from 1 cm. to 7 cm.

The method of measuring the potential required to produce the spark was that employed in Macfarlane's previous experiments.* The special arrangement of the apparatus is indicated by the accompanying plan.



A and B are the two electrodes of a Holtz machine, of which one, say A, was connected with the earth. An insulated wire joined B to the knob of a large Leyden jar C, and C was similarly connected with the disc D and with the insulated ball F. G, the other insulated ball, was connected with one of the electrodes H, of a Thomson quadrant electrometer, the other electrode K being earthed. An uninsulated metallic plate L, with a hole in the middle of it, was placed between F and G, for the purpose of diminishing the influence of F on G. This is a modification of an idea introduced by Professor Chrystal, namely, the placing of F inside a metallic cube having a hole in the side next G.

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* *Trans. Roy. Soc. Edin.*, vol. xxviii. p. 633, or *Phil. Mag.*, s. 5, vol. x. p. 389.

Having decided upon our variables, we drew out the logical plan exhibited in the Tables, and proceeded to fill in the observations systematically. We first observed the behaviour of the flame under the influence of the charge, and also the mode of passing of the spark, and then proceeded to note the readings of the electrometer for three separate discharges. It will be observed, that where the flame was in a steady state the three readings differ only by small quantities, but that where the flame was in what may be called a critical condition, the differences are relatively larger. The sign of the electricity was changed by interchanging the connections at A and B, and that was always accompanied by a simultaneous interchange of the connections at H and K, in order that any bias due to the electrometer might be eliminated. The mean differences of potential obtained were reduced to absolute measure by taking the mean of the differences of potential required to produce several sparks between two parallel plates at a distance of 6 mm. apart. For such a spark the absolute value of the difference of potential is 46·52 C.G.S. units.*

The figures sketched (Plate IV. *a*) indicate the behaviour of the flame, and the path of the spark in 24 representative cases. They are drawn in proportion to the exact dimensions.

The results for a flame of constant height (Table I.) are represented on diagram 1. The first conclusion that may be drawn is, that the difference of potential is greater when the disc is negatively electrified, excepting that for small distances there may be an equality or even a small difference the other way. The next conclusion is, that it is greater for the non-luminous flame at the smaller distances, but very much the opposite at the greater distances, particularly in the case of the negative luminous. If we look at the notes or at the sketches, we shall find decided differences of behaviour coexisting with these differences in electromotive force. In the case of the negative electrification, the flame in general assumes a pointed form, becomes diminished, and loses its luminosity partially or wholly, or if already clear, becomes more bluish. But at the smaller distances, the flame being able to form a bridge over to the disc, remains with its tip in contact, and there are none of the above changes. On the other hand, in the case of the positive

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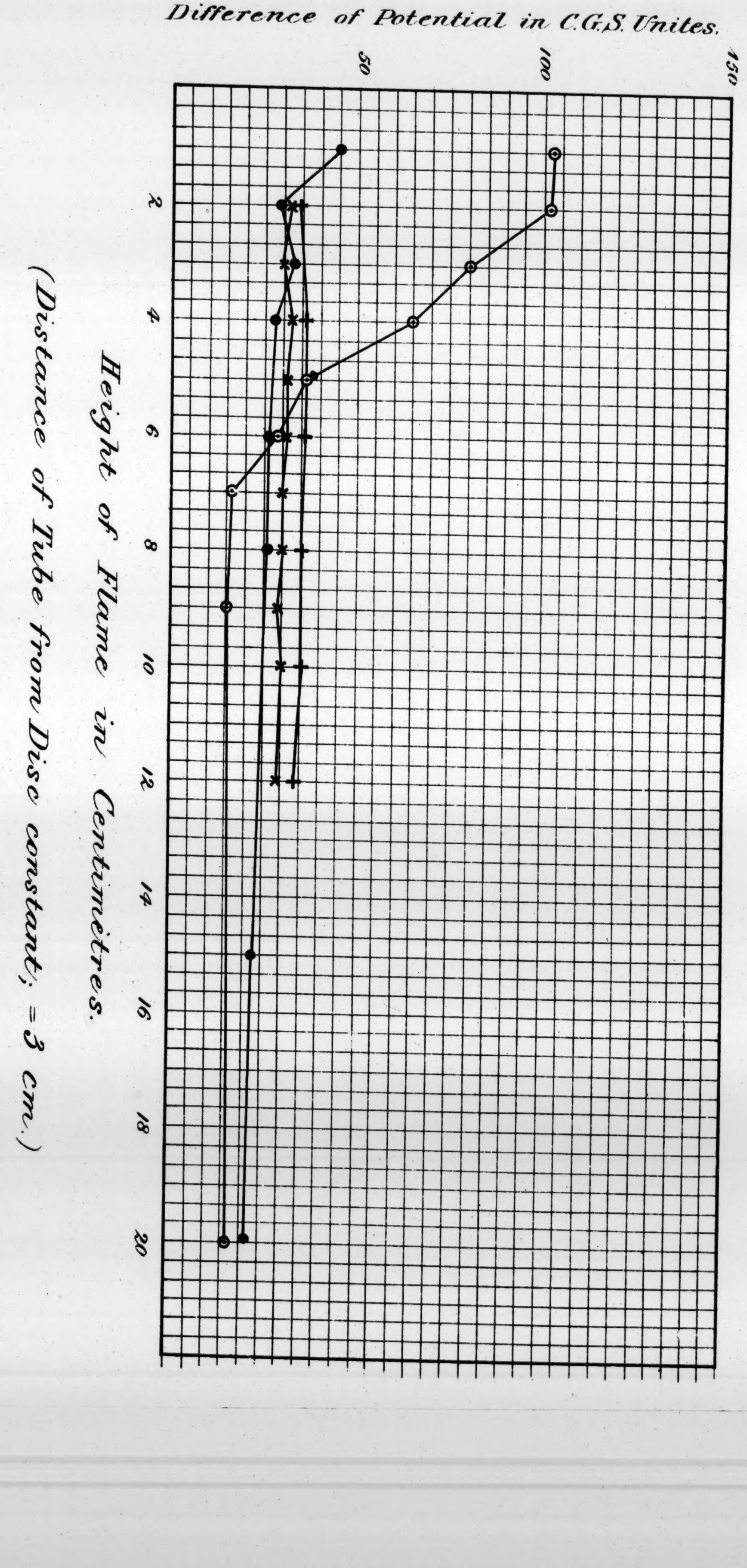
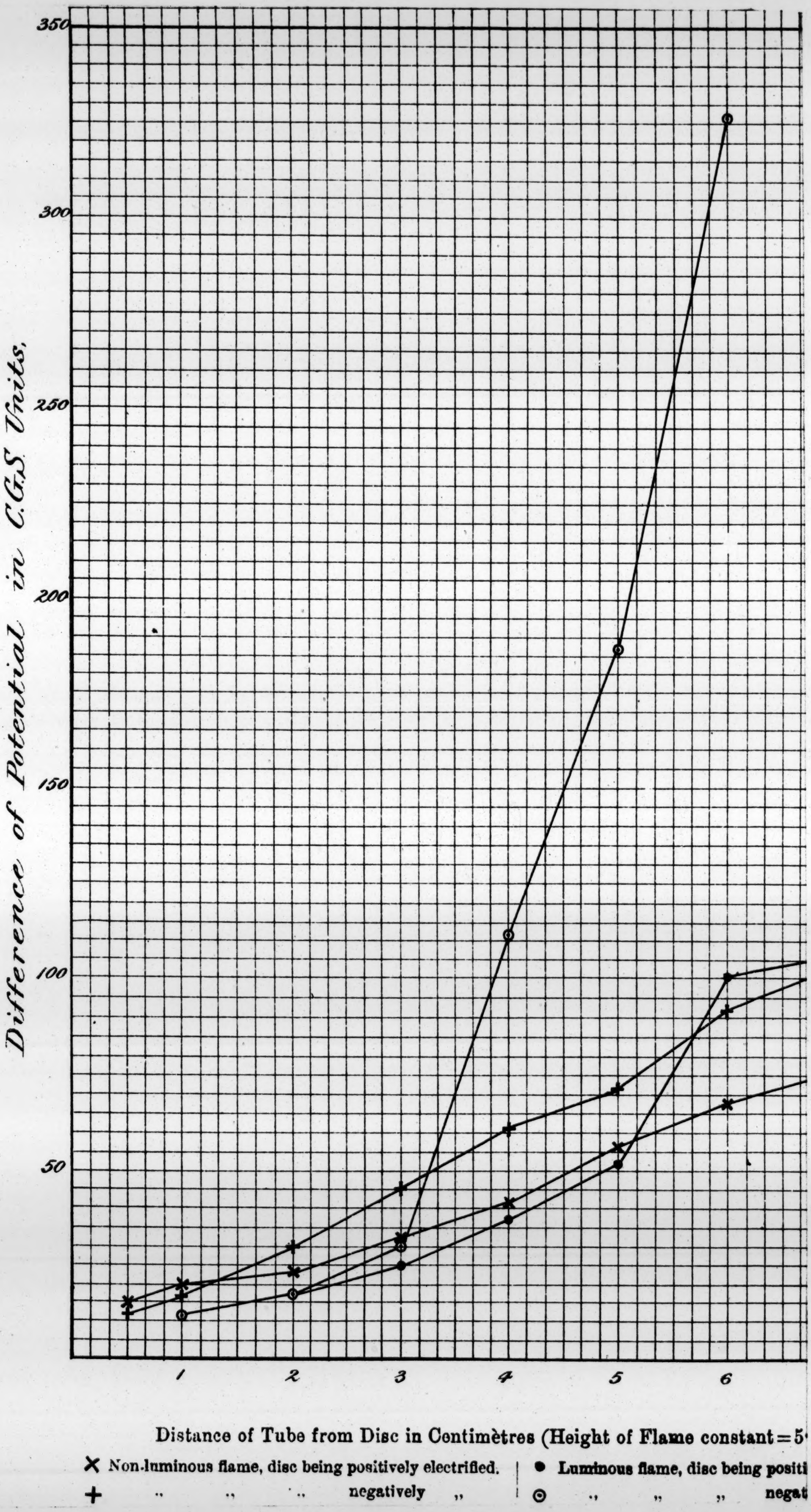
* *Trans. Roy. Soc. Edin.*, vol. xxviii. p. 652.

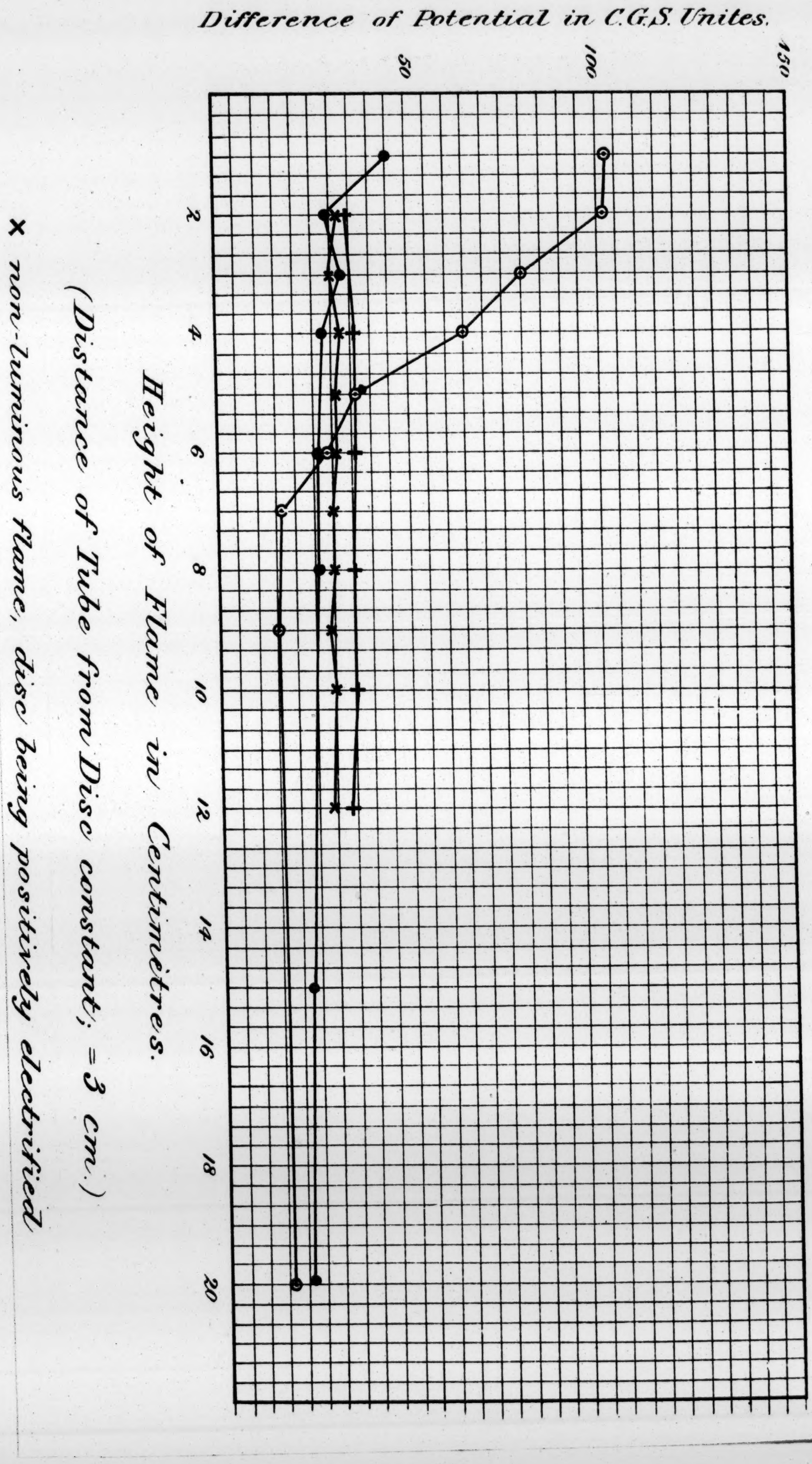


× non-luminous flame, disc being positively electrified
+ ” , ” negatively ”
● luminous ” , ” positively ”
⊙ ” ” , ” negatively ”

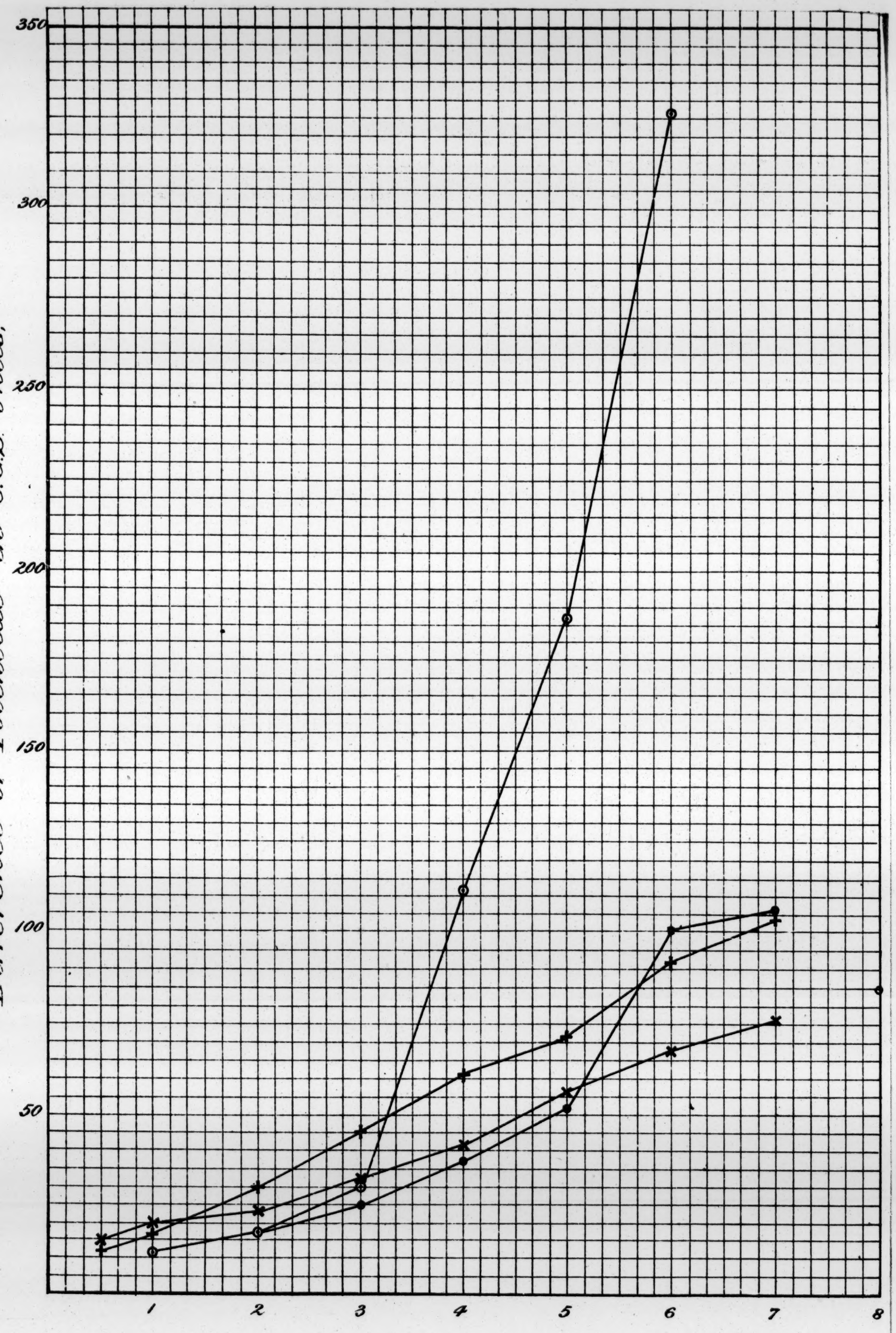
DIAGRAM 2.



Difference of Potential in C.G.S. Units,
350
300
250
200
150
100
50
1
2
3
4
5
6
Distance of Tube from Disc in Centimètres (Height of Flame constant = 5·
✕ Non-luminous flame, disc being positively electrified.
● Luminous flame, disc being positi
+ ,, ,, ,, negatively ,,
⊙ ,, ,, ,, negat



Difference of Potential in C.G.S Units,



Distance of Tube from Disc in Centimètres (Height of Flame constant = 5·5 cm.).

✕ Non-luminous flame, disc being positively electrified.
+ „ „ „ negatively „
● Luminous flame, disc being positively electrified.
⊙ „ „ „ negatively „

electrification, the non-luminous flame is not attracted powerfully, and it retains its original size and character, while the luminous one is thrown down into and over the mouth of the tube, and retains its luminosity. If there are convection currents they must be such as to throw oxygen into the flame in the former case, but not in the latter.

The observations recorded in Table II. were undertaken to test whether the difference of potential required for the spark depended largely upon the height of the flame. Where the conditions are in common with cases in the former series, the observations serve as a test of consistency; the agreement is satisfactory. Diagram 2, representing the results, in addition to confirming the conclusions drawn from the preceding diagram, shows that the variation of the height of the flame produces little change in the electromotive force, when the flame is non-luminous; also when the flame is luminous and the electrification positive, but that it produces a great difference in the remaining case, when the flame is luminous and the electrification negative, so long as the flame is not sufficiently high to reach the disc. Though the flame is attracted so as to be in contact with the disc, the discharge still passes in the form of a spark.

This investigation was made in one of the fine suite of rooms recently added to the Physical Laboratory, and in conducting it we had every facility given us by Professor Tait.

Table I.

Height of flame = radius of disc, *i.e.*, 5·5 cm.

TABLE I.—DISTANCE OF TUBE FROM DISC VARIED.

Date.	Nature of Flame.	Sign of Charge on Disc.	Distance of Tube from Disc.	Deflection.	Zero.	Difference.	Mean Diff. of Potential.	Abs. Value of Diff. of Potential.	Remarks on Appearance of the Flame.
20th Jan.	non-luminous.	+	·5 cm.	510	435	75	82	14·57	No sensible attraction; spark passes between the disc and the top of the tube.
				520	435	85			
				520	435	85			
			1 ,,	540	440	100	103	18·30	Flame has only a slight protuberance towards the disc, not diminished, nor made more bluish; spark passes to protuberance.
				550	440	110			
				540	440	100			
			2 ,,	575	440	135	130	23·09	Flame much more attracted; spark passes through a considerable portion of the flame.
				565	440	125			
				560	430	130			
			3 ,,	620	435	185	182	32·33	Flame bent still more towards the disc, not diminished, nor made more bluish; spark more through the flame, and obtained readily.
				610	430	180			
				610	430	180			
			4 ,,	675	435	240	240	42·63	
				670	430	240			
				675	435	240			
			5 ,,	750	420	330	322	57·20	
				740	430	310			
				755	430	325			
			6 ,,	800	440	360	377	66·96	
				810	430	380			
				830	440	390			
			7 ,,	840	425	415	428	76·02	Flame bent very powerfully, but not diminished or changed in colour; path of spark as much as possible through it.
				850	430	420			
				880	430	450			
		–	·5 ,,	510	430	80	78	13·85	
				515	435	80			
				510	435	75			
			1 ,,	530	425	105	97	17·23	Flame attracted so as to be in contact, diminished and made more bluish; spark passes through the flame.
				520	420	100			
				515	430	85			
			2 ,,	613	455	158	173	30·73	
				605	430	175			
				600	415	185			
			3 ,,	695	440	255	258	45·83	Flame attracted, but not in contact, assumes a toothed form broadened out across the disc, diminished, and more bluish; spark through the flame.
				700	440	260			
				700	440	260			
			4 ,,	810	450	360	350	62·17	
				780	445	335			
				790	435	355			
			5 ,,	865	450	415	408	72·47	
				880	460	420			
				890	500	390			

			6 ,,	760	190	570	525	93·25	
				745	200	545			
				650	190	460			
			7 ,,	760	200	560	583	103·6	Attracted, toothed form now lost; diminished, and made more bluish; spark through the flame. Sometimes diminished so much as to put out the flame.
				800	210	590			
				820	200	620			
3rd Feb.	luminous.	+	1 ,,	507	528	21	24	12·06	Flame repelled down; spark passes from about the centre of the disc to the edge of the tube.
				485	510	25			
				485	510	25			
			2 ,,	479	517	38	37	18·60	Flame repelled as before; spark passes more through the flames.
				481	517	36			
				481	517	36			
			3 ,,	472	520	48	51	25·62	Ditto.
				466	516	50			
				466	520	54			
			4 ,,	435	517	82	74	37·18	Flame repelled very much; spark evidently greater and from the higher part of the disc.
				430	505	75			
				440	505	65			
			5 ,,	360	470	110	102	51·25	Sputtering sound at the flame heard before the passing of the spark
				400	500	100			
				403	500	97			
			6 ,,	300	485	185	198	99·49	Great repulsion with increased sputtering at the flame; index gave no sign of discharge previous to the spark.
				280	490	210			
				290	490	200			
			7 ,,	260	485	225	212	106·5	Scintillations in the direction of the disc; spark very large; index steady some time before the passing of the spark.
				290	495	205			
				285	490	205			
			8 ,,	310	495	185	167	83·91	Flame attracted before being repelled down; index steady a considerable time before the passing of the spark.
				350	500	150			
				335	500	165			
		–	1 ,,	485	505	20	23	11·56	Flame attracted so as to be in contact; spark goes through the flame.
				480	505	25			
				480	505	25			
			2 ,,	468	502	34	36	18·09	Ditto.
				465	502	37			
				468	505	37			
			3 ,,	390	480	90	59	29·65	Flame attracted, but scarcely reaching to the disc; spark passes through the flame.
				455	500	45			
				465	506	41			
			4 ,,	370	480	110	223	112·0	Flame attracted first, then repelled, becoming horned and less luminous. Spark does not pass to tip, but about half way down.
				240	470	230			
				360	475	115			
				260	475	215			
			5 ,,	155	470	315	372	186·9	Flame repelled, losing luminosity; spark does not go through the flame.
				70	470	400			
				70	470	400			
			6 ,,	about 0	640	640	640	321·6	A large spark after some time; spark goes below the flame, not through it.

Distance of tube from disc=3 cm.

TABLE II.—Height of Flame Varied.

Date.	Nature of Flame.	Sign of Charge on Disc.	Height of Flame.	Deflection.	Zero.	Difference.	Mean Diff. of Potential.	Abs. Value of Diff. of Potential.	Remarks on Appearance of the Flame.
24th Jan.	non-luminous.	+	(cone.) 1 cm.	780	395	385	390	31·73	Slightly attracted, scintillations; spark passes through the flame.
				760	385	375			
				795	385	410			
			1·5	760	380	380	385	31·32	
				775	395	380			
				780	385	395			
			2	820	390	430	410	33·35	
				780	390	390			
				790	380	410			
			2·5	750	390	360	392	31·89	
				820	410	410			
				805	400	405			
			3	770	390	380	378	30·75	Has a protuberance towards the disc which is greatest about half-way up radius of disc; spark passes to protuberance.
				770	390	380			
				765	390	375			
			3·5	740	390	350	369	30·02	
				765	395	370			
				778	390	388			
			4	760	390	370	375	30·51	
				780	400	380			
				765	390	375			
			4·5	750	400	350	357	29·04	
				750	390	360			
				760	400	360			
			5	740	380	360	365	29·70	
				748	390	358			
				768	390	378			
			6	725	385	340	352	28·63	Protuberance opposite middle, upper part parallel to disc; scintillations pass in streams to the top; spark passes to protuberance.
				730	390	340			
				755	380	375			
		–	1	790	380	410	415	33·76	Flame thrown down below, when the spark passes.
				810	390	420			
				(off scale.)					
			2	840	380	460	432	35·14	No spark in the case of these three readings.
				805	400	405			
				860	430	430			
			3	710	390	320	368	29·94	
				745	400	345			
				800	360	440			
				840	400	440	437	35·55	Index generally steady for some time before the spark took place
				880	460	420			
				900	450	450			
			5	860	415	445	440	35·80	
				845	410	435			
				850	410	440			

			6	810	410	400	407	33·11	Spark obtained only after a considerable time.	
				760	380	380				
				832	390	442				
			2	740	380	360	410	33·35		
				810	380	430				
				820	380	440				
			3	765	355	410	447	36·36		
				830	385	445				
				835	350	485				
31st Jan.	luminous		(tip.) 1	360	440	80	78	44·90	Flame slightly attracted; scintillations after the passage of the spark.	Never loses luminosity except perhaps in the case of 1 cm.
				363	439	76				
				362	439	77				
			2	368	428	60	50	28·78	Top of flame repelled down into the body of the flame.	
				385	425	40				
				370	420	50				
			3	380	436	56	55	31·66	Ditto.	
				380	436	56				
				381	433	52				
			4	390	440	50	50	28·78	Scintillations after the spark; spark does not pass through any considerable portion of the flame.	
				388	434	46				
				380	435	55				
			6	390	440	50	50	28·78	Repelled down so as to overlap the top of the tube.	
				389	438	49				
				385	435	50				
			8	403	452	49	46	26·48	Ditto.	
				408	451	43				
				405	452	47				
			15	405	450	45	40	23·02	Lower part of flame most affected; flame thrown down into and over tube; index very shaky before the passing of the spark.	
				395	435	40				
				396	430	34				
30th Jan.		—	1	450	640	190	179	103·0	Tip attracted towards the disc, the yellowness disappears; no sign of any discharge before the passing of a large spark.	
				460	640	180				
				480	646	166				
			2	460	620	160	177	101·9	First attracted, then yellowness disappears, then repelled and becomes like a blow-pipe flame; large spark finally.	
				465	650	185				
				240	425	185				
			3	270	408	138	138	79·44	Ditto.	
				260	405	145				
				300	430	130				
			4	300	410	110	113	65·04	Flame attracted so as almost to touch, then becomes blue, and becomes diminished as before, taking the form of a twisted fang pointing to the disc; large spark.	
				310	430	120				
				290	400	110				
			5	372	433	61	63	36·26	Very nearly touching; good deal of yellow remains, not diminished much; horns at extremity of flame stretching out to disc.	
				371	437	66				
				380	442	62				
			6	390	442	52	50	28·78	Touching, remains in contact, carbon deposited on disc for the first time; spark through the flame.	
				392	442	50				
				392	442	50				
			20					17·16	A still higher flame was tried; contact permanent, with carbon deposited on the disc.	

2. Observations on Vegetable and Animal Cells; their Structure, Division, and History. Part I., The Vegetable Cell. By J. M. Macfarlane, B.Sc. Communicated by Professor A. Dickson.

3. On some Points in the Anatomy of the Nervous System of the Pond Snails, Planorbis and Lymnæus. By F. E. Beddard, B.A., New College, Oxon. Communicated by Mr P. Geddes.

The best figures of the nervous system of these animals are those of Lacaze-Duthiers, in his Paper *Sur les Otocystes des Mollusques*, and in that *Sur le Système Nerveux des Gastéropodes.** By a careful study of the nervous system of these two gasteropods, chiefly by cutting sections, I have discovered one or two small points in their anatomy which, as far as I can make out, have hitherto escaped attention.

These two types, though so closely allied, differ to a considerable extent in the arrangement and structure of certain of their ganglia; compare the figures given by Lacaze-Duthiers of the nervous system of Lymnæus on Plate xvii. in Volume i. of his *Archives* with that of Planorbis on Plate iii. of the same volume. It will be seen at once that the cerebral ganglion of Lymnæus is far more complicated than that of Planorbis, consisting of five separate lobes, while that of Planorbis appears to be made up of not more than two.

Otherwise, the number of ganglia in the two is the same, but the asymmetry is different, the larger parietosplanchnic ganglia being on the right side in Lymnæus and on the left in Planorbis.

By cutting several series of sections of the whole nervous system of Planorbis and Lymnæus, and arranging them carefully in order, one or two more points of difference in structure have been noticed. In fig. 1, which represents a complete section taken through the nerve collar of Lymnæus at the level of the pedal ganglia, it will be seen that these ganglia are united by a double commissure, the lower of the two commissures is much slighter than the upper, and was far more difficult to find; the upper stouter

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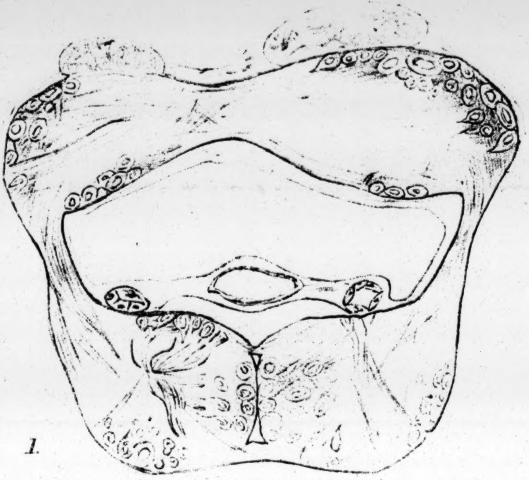
* *Archives de Zool. Expérim. et Générale*, vol. i. 1872.



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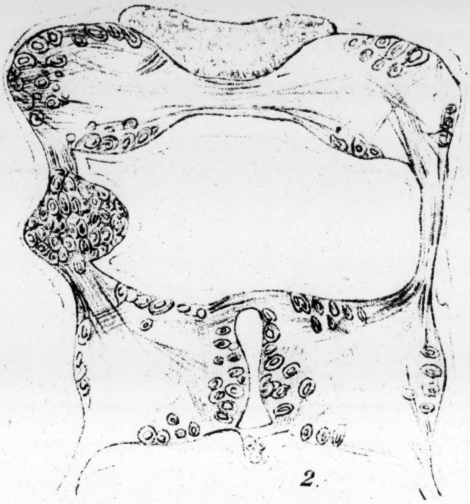

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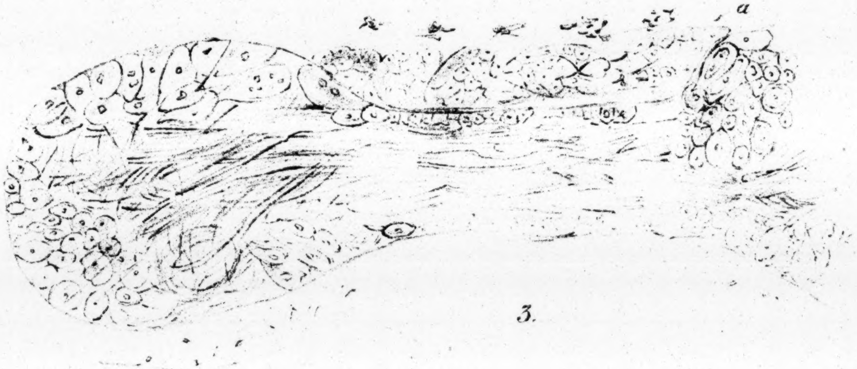

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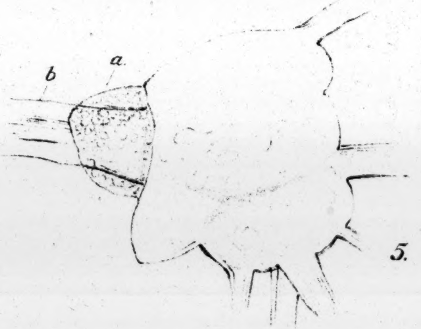

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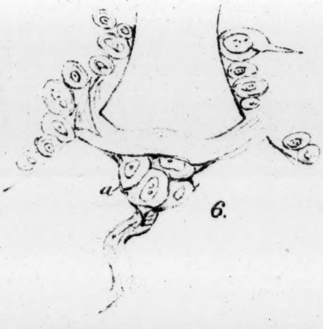

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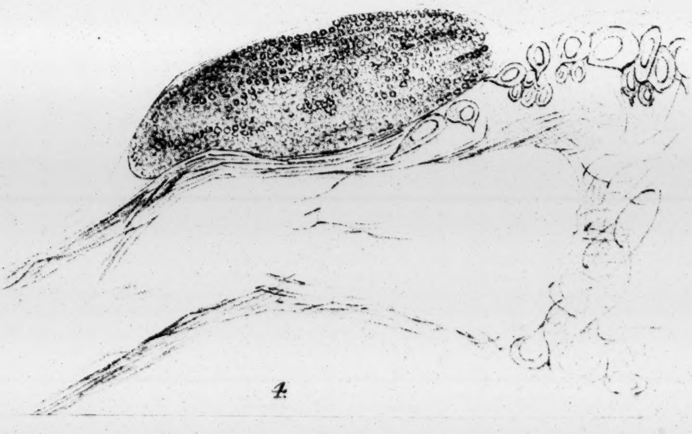

4.

7.

commissure is shown in every series of sections prepared. M. de Lacaze-Duthiers * figures and describes three distinct commissures, of which the two upper are stout, while the lower one, which evidently corresponds to the lower one of the two that I have described, is slender, and gives off from the middle an unpaired nerve running backwards, the distribution of which was uncertain. Whether this double (or treble) commissure is an expression of the compound nature of the pedal ganglia, which are generally supposed to have originated from a primitive ventral ganglionated chain by the fusion of some of the ganglia and the suppression of others, is doubtful; judging from analogous cases, it would appear probable that it is not so. M. Yung,† in a paper on the nervous system of the Decapod Crustacea, describes the abdominal ganglia as being joined by three commissures; as there is one ganglion to each abdominal segment in the Macrura, it does not seem possible that they can have been originally represented by several ganglia. So much for Lymnæus. In Planorbis the arrangements are a little different, there are the same two commissures (fig. 2), but the lower one is much stouter than it is in Lymnæus, and therefore is much more easily seen, though it seems to have escaped notice.

The great point of difference between the two types studied is, that in Planorbis there is a small unpaired median ganglion which, lying between the pedal ganglia and on the lower of the two commissures, unites them. This is itself connected with one or both of the pedal ganglia by a commissure, which, though independent of that uniting the two pedal ganglia, yet, as is shown in the figure (fig. 6), lies upon it. This ganglion is shown in figure 2 in position, and in figure 6 more highly magnified, so as to bring out its constituent cells. It is very small in extent, not more than four or five cells in thickness, but is almost impossible to miss in a carefully-cut series of sections; the cells are of uniform size, and not large. From the under surface an unpaired nerve is given off, which is no doubt homologous with that described and figured by M. de Lacaze-Duthiers in Lymnæus, but in Lymnæus I have found no trace of this small unpaired lobe. The unpaired nerve, on the contrary, does not seem to be peculiar

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* *Loc. cit.*, pl. xvii. fig. 4.

† Emile Yung, "Système Nerveux chez les Crustacées Décapodes," *Arch. Zool. Expér.*, 1878, vol. vii.

to these two species; it is figured by Spengel [*] in Gastropteron and Aplysia, and by Von Ihering [†] in these two types as well as in Bulla and Acera. A double commissure between the pedal ganglia is very general, and in a few cases, as in Lymnæus, according to Lacaze-Duthiers, there is a treble commissure; a glance at Von Ihering's plates will show this. Whether this ganglion just described is limited to Planorbis, or whether it is general, I do not at present know, but hope to study the nervous systems of a number of Mollusca, with a view of determining its nature and distribution.

In the same two sections (figs. 1 and 2) may be seen a mass, unpaired in Planorbis and paired in Lymnæus, lying above the cerebral ganglia, on the commissure uniting them. It has been hitherto regarded merely as a part of the cerebral ganglion, and if it is really so, its structure is very peculiar; from studying it in sections and by teasing, it appears to me to be rather of a glandular nature, judging from its structure and relations.

It will be best to commence with a description of this structure in Lymnæus, and I may say that the description below refers to *Lymnæus stagnalis*, while the species of Planorbis described is *Planorbis corneus.* Fig. 5 represents the cerebral ganglion of Lymnæus, and that portion of it lettered *a* is now under discussion; it will be seen that the commissure *b*, uniting the ganglion to its fellow, has in reality nothing to do with this lobe, but takes its origin from the larger part of the ganglion, and merely passes under the lobe *a*. In the fresh ganglion this part is readily distinguishable from the rest from its being of a whitish colour, containing none of the red pigment which is distributed universally in the cells and their processes of the rest of the cerebral ganglion and in the other ganglia. Lacaze-Duthiers says of it: [‡] "Il se fait distinguer sur l'animal vivant par son opacité et sa teinte blanchâtre, très saillant surtout dans le *Lymnæus stagnalis*, il l'est un peu moins dans les deux autres espèces. Il est formé de corpuscles relativement fort petits et qui ressemblent à ceux que l'on trouve mélangés aux gros corpuscles du milieu du ganglion. La grandeur de ces corpuscles est uniforme. Ils semblent être des noyaux qui ne dépassent pas de faibles proportions. Aussi ne trouve-t-on jamais mêlés à eux ces grands corpuscles ganglionnaires qui occupent le milieu du cerveau. . . . . Arrondi du côté de la commissure, ce lobule semble séparé par deux lignes formant un angle du côté du ganglion en dehors, on croirait que le névrilème l'entoure et l'isole."

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[*] "Die Geruchsorgane und das Nervensystem der Mollusken," *Zeitschr. für Wissensch. Zool.*, 1881, plate xvii. figs. 7, 8.

[†] *Nervensystem der Mollusken*, Leips., 1877, plates iii. and iv.

[‡] *Loc. cit.*, p. 443.

The author goes on to say that this mass is found in all the Pulmonata, and that researches are wanted to establish its functions and relations with other parts of the ganglion. It is therefore evidently something distinct from the rest of the ganglion. The absence of the red pigment, which is so characteristic of the nervous system of Lymnæus, is so very remarkable, if this lobe is to be regarded as merely a part of the cerebral ganglion; and again the fact that it is divided off from the rest by a connective tissue lamella, while none of the other lobes into which the cerebral ganglia are portioned show any signs of such a complete separation, seem to point to its being a distinct structure.

Fig. 4 represents a vertical section taken through the cerebral ganglion of one side; *b* is the commencement of the commissure which unites it to the other cerebral ganglion; *c* is the commissure uniting it with the pedal ganglion; *a* is the "white lobe" of the ganglion. A glance at this drawing will show at once how different it is in general appearance from the rest of the cerebral ganglion; it is made up of small rounded cells packed closely together, so as to give the appearance occasionally of being polygonal. When separated by maceration in weak chromic acid and subsequent teasing, each of these cells is oval or roundish, occasionally three-cornered with the corners rounded off; the nucleus is large, but not nearly so large in proportion as the nucleus of the ordinary nerve cells from the ganglia; they are very similar in general appearance to certain glandular cells from the penis of the same animal, but a good deal smaller. No signs of any nerve fibres either within the mass or connecting the two were visible.

In sections of the nervous system prepared with different reagents the appearances presented by the "white lobe" are very different from the rest of the ganglion. When stained with gold chloride, the ordinary nerve cells are coloured with various shades of blue and purple, the nuclei being left altogether unstained, while the cells of the "white lobe" are tinted of a uniform pale lilac, there being but a very slight distinction between the nucleus and the cell protoplasm. This "white lobe" also presents the appearance of a firm solid cellular mass, while the other part of the cerebral ganglion consists of an outer sheath of nerve cells of various sizes, and an inner core of nerve fibres. When hardened and stained by osmic acid, there is still a noticeable difference; the ordinary nerve cells within the ganglia are coloured brown, the nucleus being left unstained, or coloured more or less faintly; while the cells making up the white lobe are coloured on the whole much more faintly than the ganglion, but the nuclei are rendered conspicuous by being stained more deeply than the surrounding protoplasm.

The homologous structure in Planorbis (see figs. 1, 2) is a large single mass lying over the commissure uniting the two cerebral ganglia; it is figured by Lacaze-Duthiers,* but is not specially described by him. Though this mass in Planorbis is single, it has a deep depression in the middle, which gives it a kidney-shaped outline in transverse section. In structure it is altogether similar to the corresponding part in Lymnæus, that is to say the cells which make up the mass are quite alike in both animals, but their arrangement is rather different in Planorbis. As is shown in figure 3, the whole mass is distinctly lobulated, the lobules being separated from each other by trabeculæ of connective tissue; it is not unlike the salivary gland of the same animals, but in a number of sections both structures were visible in the field of the microscope at once, and then there was no possibility of confounding them; the cells of which the salivary gland is composed are a great deal larger, and the nucleus is far more distinct—there are of course numerous other minute points of difference; but what I wish to dwell on in the present paper are the points of resemblance rather than difference, to show that this "white lobe" must be considered as a gland.

The facts then about the anatomy of the "white lobe" in Planorbis appear to point to one conclusion—that this part of the cerebral ganglion must not be considered as really forming a part of the cerebral ganglion, but as being distinct and of a glandular nature; and if this is granted in the case of Planorbis, it must be the same with Lymnæus, as their position and general resemblance leaves no room for any other view than that they are homologous structures. Moreover, there is really nothing which would make it unlikely on *a priori* grounds that this interpretation is the right one. M. Joliet has recently come to the conclusion that the so-called ganglion of Melicerta * is not a ganglion at all, but a gland. What the nature and homologies of this gland may be, is a question which can only be decided by a careful study of other Mollusca and of its development; several views as to its nature obviously suggest themselves, but in the absence of any more comprehensive information than is contained in this paper, it would be mere waste of time to consider any of them.

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* *Loc. cit.*, pl. iii. fig. 10.

PLATE I.

Fig. 1. Transverse section through nerve collar of Lymnæus, × 20.

Fig. 2. Transverse section through nerve collar of Planorbis, × 20.

Fig. 3. Transverse section through cerebral ganglia of Planorbis, showing glandular mass (*a*) lying above commissure, × 120.

Fig. 4. Transverse section through one cerebral ganglion of Lymnæus, showing glandular mass (*a*) lying above commissure, × 120.

Fig. 5. Cerebral ganglion of Lymnæus, showing commissure (*b*) which unites it to its fellow, and glandular mass (*a*), × 20.

Fig. 6. Transverse section through pedal ganglion of Planorbis (*a*), is the unpaired small medium ganglion, × 75.

Fig. 7. Single "acinus" from glandular mass of Planorbis, × 300.

Fig. 8. Nerve cell (*a*) from cerebral ganglion of Lymnæus and "gland cells" (*b*), × 300.

4. A Critical Examination of two cases of unusual Atmospheric Refraction described by Professor Vince. By Edward Sang, C.E.

The two phenomena, the subjects of the present paper, have found a place in the current popular scientific literature of the day, and exercise a considerable influence on the opinions of the casual votaries of science, and even of some of those who are its regular cultivators. For that reason I shall go more into detail than otherwise would have been needed.

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* *Comptes Rendus*, Nov. 7, 1881.

In the beginning of the session Professor Tait read a paper on Mirage, and exhibited to the Royal Society of Edinburgh an enlarged representation of an aërial phenomenon described by Professor Vince. The Professor of Mathematics inquired of me my opinion as to the explanation offered; and I now reply to Mr. Chrystal's inquiry indirectly, not by discussing in any way Mr. Tait's analysis, but by examining the major proposition, the reality of the phenomenon.

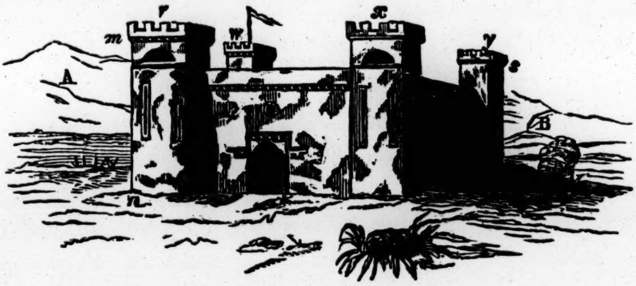
The sight of the enlarged representation recalled to my mind matters connected with my college and even with my school days. The name of Vince is to me a familiar one; his elementary treatise on Astronomy was our text-book at school and I had read, with not less pleasure than profit, his little work on Hydrostatics; his large work on Astronomy stands on my book-shelf for frequent reference. Any observation made by Vince thus naturally arrested my attention and pre-secured my confidence. Nevertheless, there were features in that drawing which awakened a long-confirmed distrust, and which seemed to me to need a careful examination.

We boys of twelve or thirteen years, had determined the latitude by our own observations made with the school sextant and artificial horizon. We knew of the augmentation of the moon's diameter, and by actual measurement had satisfied ourselves that the enlargement of the horizontal moon is only an error in judgment due to the seeming increase of distance. The stories of phantom ships and giant spectres were classed among those of ghosts and hobgoblins.

During my first session at college, an incident occurred to intensify this chronic distrust. One misty morning, while going to class from my lodgings in Gayfield Square, and when at Picardy Place, I was startled by the apparition of enormous spectres walking in the sky. The first momentary astonishment being over, the apparition had to be scrutinised. The outline of the Calton Hill was with difficulty traced through the mist; the spectres were walking thereon; it was therefore a case of atmospheric magnification analogous to the seeming enlargement of the horizontal moon; so by moving so as to bring the figures to contrast with the houses near, it was easy to see that the angular magnitude was that of human beings on the hill. The illusion was due to the false idea of distance, but the vividness of the first impression showed how readily a mistake may be made, and left on my mind a deep conviction of the absolute need for a close scrutiny of all such appearances.

I am then, necessarily, in the position of an advocate on the opposite side engaged in cross-examining a witness.

In the article OPTICS of the eighth Edition of the *Encyclopædia Britannica*, an article by Sir David Brewster, there is recounted a case of Atmospheric Refraction observed and described by Professor Vince; it is illustrated by a copy of a view of the phenomenon. A single glance at that picture, by any one habituated to observation, is enough to convince him that the phenomenon thereby depicted could never by possibility have been seen. It is a view of Dover Castle as seen from Ramsgate, and represents a rectangular building with a square turret at each corner. Passing by, for the present, its most glaring feature, I remark that the faces to the right hand are in deep shadow, the shadow of the building itself upon the ground is also to the right. The faces toward us are in sunshine, and the tower on the left throws its shadow on the centre wall as if from a sun behind us to the left at an azimuth of some 40°. The side-wall again forms a shadow on the right hand distant tower at an elevation of some 60°. Now Dover is almost exactly S.S.W. from Ramsgate, wherefore the sun must have been in the N.E. at an elevation of 60°; a direction from which the sun never shone upon Great Britain. The time of the observation is stated to have been 7 o'clock in the evening of the 6th August. At that time the sun was about to set in the W.N.W. Surely the Professor of Astronomy at Cambridge could not have made a blunder which puts the sun in the neighbourhood of the star Vega, circumpolar to us! The article in the *Encyclopædia* concludes with "See *Edinburgh Transactions*, vol. iv. p. 245;" and as evidence at first hand is better than evidence by hearsay, we shall consult the *Transactions*. We there find the original description of the phenomenon as read before the Royal Society of Edinburgh, on the 5th of Janu-



ary 1807, accompanied by an engraving well executed by D. Lizars.

The engraving shows a rectangular structure with a tower at each corner, drawn in what is usually called *perspective.* The west faces of the building are in bright sunshine; the north faces are less brilliantly lit, but are not in shade, and the N.W. turret casts a shadow on the middle North Wall.

Brewster had changed the direction of the source of light from W. to E.; he had put a gate-way in the north wall where Vince has none; had altered considerably the style of the architecture, and had, in one respect to be afterwards noticed, improved the drawing.

Recollecting that Dover is S.S.W. from Ramsgate, we perceive that the trend of the picture plane is W.N.W.; now the west face of the building is shown as inclined to the line of sight toward the west; its trend must be about S.W. by S., and therefore that of the N. face about N.W. by W. Hence, looking at the shadow upon that north face, we judge the sun to have been in the N.W.; and, looking at the slope of that shadow, to have had an altitude of about 44°, and this at 7 h. on the 6th of August. On putting the celestial globe into position for the time stated, we find that the sun must have been shining from among the small stars of the Great Bear. The shadow of the building upon the ground to the east, corroborates the story. Thus far the Astronomer; next the Architect; he says, and at a glance, there is no member of the structure which could, under any circumstances, have caused the shadow as shown in the figure.

Let us go more carefully into the matter. When a drawing of any rectangular structure is given in perspective, it is easy to deduce the distance of the point of sight from the picture, as well as the relative positions and proportionate sizes of the parts. Taking the extreme bounding lines as the basis, we find the vanishing point for the north face to be 193·2 inches to the left; that for the west face to be 3·7 to the right, counting from the middle of the picture. These give 26·6 inches for the eye's distance from the paper, and an inclination of 7°·50′ of the north face to the picture plane.

The bearing of Dover from Ramsgate, computed from the geographical positions, is 20°·4′, west of south, hence the trend of the north face must be 27°·54′ north of west. But the sun's amplitude at 7 h. on the 6th of August is only 21°·57, and the altitude 4°; wherefore the north faces of the building should have been in shadow.

The distance between the two places is 14½ miles, which on the scale of the drawing is represented by 26·6 inches. Computing thence the dimensions of the building, we find its

Length = 16,000 feet = 3·2 miles
Breadth = 7,346 „ = 1·4 „
Height = 4,895 „ = 0·9 „

which would make Dover Castle to be, not the Eighth, but THE wonder of the world.

There are many unacquainted with the laws of perspective drawing; for their sake we may take another view. It is generally known, that the apparent size of an object, its space upon the picture, diminishes as the distance increases. Now the breadths, measured on the paper, of the north-west and south-west towers are 51 and 28 hundredths of an inch; the nearer is 14½ miles away, wherefore, since 28 : 51 :: 14·5 : 26·4, it follows that the other is 26·4 miles off; so that from north face to north face of the towers must be 11·9 miles, or the whole length more than 12 miles! The drawing must be sadly out, for this is nearly four times what was previously found.

Again, if we look at the western sides of the turret-tops, we observe the depth of the parapet to decrease rapidly toward the south. On the north-west tower the diminution is almost exactly as two to one; wherefore its farther corner must be twice as far from us as the nearer, and so the top of the tower must measure 14 miles. In Brewster's drawing this most outrageous of all the blunders is rectified.

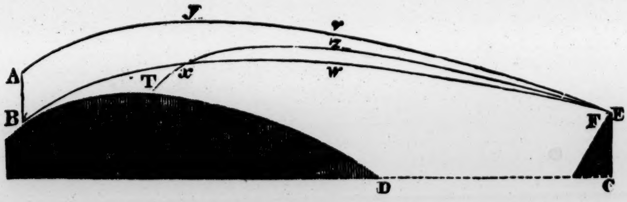
These prodigies, however, are far outshone by the artistic extravagance of the foreground; there the blades of grass expand at our feet, and the very veins of the leaves are seen.

All this was seen through a good telescope which the Professor could hand to his companion. I have somewhere read of a spyglass bringing people so near that you could hear them speak; this one must have had the equally wonderful property of transporting the user bodily to within a hundred fathoms of a building fourteen miles away.

Evidence of this character would not be received in support of the most common-place assertion; but the phenomenon in question, far from being common-place, may, rather, be described as miraculous. Dover Castle is situate on the south side of a hill; Ramsgate is far away on the north side; and the tops of the turrets of the Castle are usually seen from Ramsgate just above the hill. But, on this occasion, the Castle was seen as if it had been brought to the north side, and, apparently, in its natural position with regard to the turrets. Vince tells us that the light from the hill undoubtedly reached the eye, but that it was so overpowered by the greater light from the Castle as to be unperceived; he places before us this drawing to represent the Castle as he saw it, and proceeds to explain how this vision may have been brought about.

For this purpose he constructs an abstract figure in which AB represents the Castle, T the top of the hill, E the place of the spectator; and he draws two curved lines A$yv$E, B$xw$E to represent the paths of the light from the top and bottom of the Castle to the eye. He draws also the curve T$xz$E as the path of the light emanating from the top of the hill, crossing B$xw$E at the point x, and having its part xzE between the two first mentioned lines. He says, "Then it is manifest that such a disposition of rays will produce the observed appearance . . . . . The phenomenon cannot otherwise be accounted for."

According to his explanation, A$yv$E and B$xw$E are the paths of the light in the usual state of the atmosphere, and the phenomenon in question is produced by the rapid curvature of the part xz of the ray T$xz$E; this rapid curvature being due to a variation in the density of the air between yvE and xwE.



Supposing, merely for the sake of fixing our ideas, the height of the tower BA to be 100 feet; the separation of the curves at x and y may be say 60 feet, within which distance this extraordinary disposition of the air must exist, and not beyond on either side, for otherwise the paths AyE, BxE would be deranged. In the ordinary state of the air, the light would pass in the usual way below the curve $BxwE$; and even now, since the extraordinary condition does not extend below that line, it will still so pass. Wherefore, according to this explanation, T should have been seen double. Moreover the picture* tells us that light from between B and A reaches the eye in directions intermediate between vE and wE, and now we have this most wonderful fact that the air situate between the extreme rays has two indices of refraction, one for Dover Light, one for Hill Light. But more absurd still;—the rays AyE, BxE are the usual paths of light, whence it necessarily follows that the point B is usually visible from E, and thus the phenomenon made clear by this explanation is:—"that the Castle being usually seen clear above the top of the hill, was, on this occasion, seemingly imbedded in it, the ridge having been apparently raised," exactly the opposite of what Vince imagined himself to be explaining.

We may get a clear view of the matter by considering the broken branch in the foreground of the picture. This branch is, in reality, beyond yon far-off hills B; and we have to explain how it can come to be seen as represented.

One, indeed the obvious, supposition is, that the matter forming the hill had become translucent for Dover Light, which hypothesis will account also for the feebleness of the Hill Light. Or we may suppose that the rays of light from Dover had skimmed over the high ground B, had descended on the northern side until they found out, each the true continuation of its path, and then had come straight on to the eye. Of the two hypotheses, the former appears to me to be the simpler and the more comprehensible.

Having thus far discussed the information given to us by Professor Vince, we may examine what is to be got from other sources.

On a small map of Dover published by Messrs. Johnston, the Castle is shown as consisting of several detached buildings, none of which can be reconciled with the form and position inferred from the perspective drawing; but, in the course of three quarters of a century, the buildings may have been changed. To the north of the Castle, in the direction of Ramsgate, there is marked St. Mary's church in ruins, which surely should have been seen in the foreground of the Castle.

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* The proprietors of the *Encyclopædia* have kindly lent the preceding woodcuts.

On consulting the Ordnance map of the district, done in 1818, and brought up to 1880, and drawing on it a line from Dover Castle to Ramsgate, we find at the distance of 12 miles from the latter place, a village called East Langdon with 22 buildings; a little farther north, another called Marten with 17; then Appleton with 6. The absence of contour lines prevents me from determining the heights; but, taking Vince's statement that the hill is 12 miles away, these villages must be just in such a position as to occupy seemingly the position of the lower parts of the Castle.

Which then is the more credible:—That all the wonders just discussed should have been real:—or that an indiscriminating observer should have deluded himself by the fancy that some of these buildings were parts of the Castle?

Such things do not often occur in the history of physical science. Generally assertions by whomsoever made can be and are tested by the reproduction of the alleged circumstances; but in a case such as that before us, no one can repeat or verify the observation, nor even make one analogous thereto; and therefore it behoved the observer to have been particularly careful as to what he saw, and as to how he recorded it. We have seen that the record is an aggregate of impossibilities.

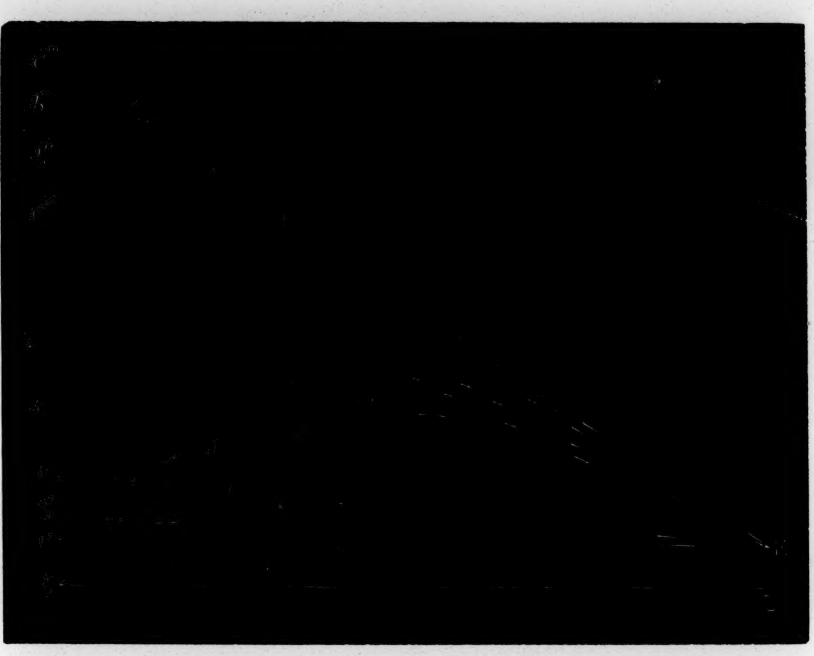
It is indeed strange that such a gross substitution should not have been instantly detected; and still more strange that Brewster should have transferred the account into the *Encyclopædia*, and even improved the drawing, without having perceived that the mere fact of its being in perspective is absolute proof of its untruth. Just as a story is the less credible, so there would seem to be the less need for examination. This is seen also in the succeeding paragraph, wherein Sir David supports the idea of an atmospheric mirror by the evidence of a girl who, while gathering flowers on the hill-side, saw her image and her very features reflected from a thin mist rising from a marsh; and he strengthens that evidence by the inquiry of her friends who were waiting for her below as to "who was with you on the hill?" never perceiving that this question supplies the simple intelligible solution of the mystery:—that the young woman had mistaken another person for her own image. By such careless treatment of evidence the growth of these phantasies is encouraged.

In a popular work on Astronomy which has had a considerable circulation, these two among other cases are given of wonderful atmospherical phenomena, and an experiment is detailed exhibiting the marvellous powers of reflected light. A bottle half filled with liquid is held before a concave mirror, when lo! the inverted image has the liquid in its lower half! the mirror is able to invert the bottle, but cannot reach its contents. With the author of this work the stellar nebulæ become huge concave reflectors. He exhibits also a drawing of a stately ship, her sails well filled by the breeze, and below, heeling over symmetrically, her inverted image, and below that again the topmasts of a ship hull down: he tells us that the unseen ship is the reality, the others only her images caused by atmospheric refraction. It has not entered into his head to consider that such a breeze would blow to the winds all the thereunto necessary refracting surfaces. This is an improved edition of the second phenomenon, the subject of the present paper.

In the 89th volume of the *Philosophical Transactions*, Professor Vince describes a phenomenon seen by him from Ramsgate; the appearance was that of the mast-head and upper rigging of a ship hull down, in the air above which an inverted image was seen, having above it again an erect image of the same ship. He explains the conditions of the atmosphere needed to produce such appearances in the following manner:—

Having drawn a straight line *bz* to represent the surface of the water, raised a perpendicular *ba* for the ship's mast, and placed the eye *e* above *z* to indicate the observer's height above the sea-level, he draws two curved lines *bs*E, *ar*E for the usual paths of light from the hull and from the top-mast. The directions of the tangents to these two curves define the apparent position *b′ a′* of the vessel. Here the dominant idea is the curvature of the rays; and this idea has led him to show the paths as curved while the surface of the sea is flat. Had he intelligently considered the matter he must have seen that his illustration demonstrates the impossibility of our seeing a ship hull-down. If the path of light were more curved than the surface of the ocean, we should be able to see all round, and, with transparent air and good glasses, to view our own backs, twenty-four thousand miles off. The line *bz*, instead of having been drawn straight, should have risen from *b* to graze the line *ar*E and should then have descended to *z*, completely intercepting the ray *bs*E.

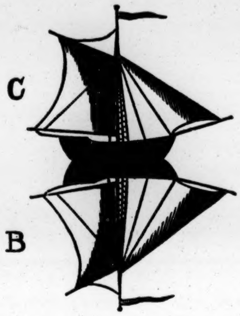
In order to explain the unusual images, Vince represents rays proceeding from the points *b* and *a*, rising in the air and then bending down to reach the eye. This reflexure is caused by a rapid change in the refractive power of the atmosphere.



He has not, however, given any measurement by help of which we may estimate the extent and manner of the refraction; he only mentions that the proportions of the distances were noted; yet the measurements were at his hand. He was using a telescope magnifying 30 or 40 times, and we infer from his narrative that the instrument was on a stand. Now, with scarcely any trouble, he might have ascertained exactly the power, and have measured the angular aperture of the field; indeed to an astronomer these are matters of course. He could easily have compared the sizes and distances with the width of the field-bar. As it is, we cannot tell what may be the angle of elevation of the upper image.

The drawing is that of a fore-and-aft rigged sloop, a kind of coasting vessel never built very large; the existence of ratlins would indicate it to be a large one of its class, and, for the purpose of a rough estimate, we may take the top-mast as 60 feet above the water.

The eye was 25 feet above the sea-level, wherefore the edge of the actual horizon must have been distant 6½ miles. In proportion, there must have been about 35 feet of the height concealed, so that the ship must have been $7\frac{1}{2}$ miles beyond the horizon or altogether 14 miles away. Taking the proportions shown in the figure, the top-mast of the upper image must have appeared at the height of 210 feet above the water edge, giving an angular elevation of about ten minutes of a degree (9′ 46″).



The ray of light in rising from the ship, encountered air of less and less refractive power, and so was bent downwards to become horizontal, after which the same curvature was repeated inversely; hence it follows that the index of refraction of the air at the top of the curve must have been less than that of the air below, in the ratio of cosine 10′ to radius. Assuming for the season of the year, the temperature at the ground to have been 15° or 59° Fahr.; its index of refraction comes out 1·0000283; wherefore the upper air must have had the index 1·0000232, and its density must have been what is due to a fall of 5·1 inches with the same temperature or to a rise of 86 degrees Fahrenheit with the same pressure.

If we suppose the air to have been of its usual density almost up to the limit of height and then to have become suddenly rare, the path of the light would have consisted of two straight lines united by a short and quick curve, and the height would have been the half of 210 feet. But, if the change of density be assumed as gradual, the ultimate height must have been less than the half; for a parabolic curve it would have been the fourth part. But all analogy tells us that the curvature becomes less as we ascend; wherefore the vertex must have been at not more than 50 feet above the sea-level.

Thus, in order to produce any phenomenon like that described by Vince, either the barometric pressure must have decreased at the average rate of one tenth of an inch for each foot of rise, or the temperature must have increased at the rate of 1°·7 Fahr., or nearly one degree centigrade for each foot, ultimately to reach the extraordinary heat of 145° Fahr. And this condition of the air's density must, according to the narrative, have subsisted for hours over the whole sea-reach of Ramsgate, yet, in the course of his observations, the Professor himself went to the height of 80 feet, and has not recorded anything remarkable in the state of the air there. Nor is this all; the ships came and went; there must have been a fresh breeze blowing, notwithstanding of which this wonderful, this inconceivable condition of the atmosphere continued.

Though at such a great distance, the minute details of the upper rigging are visible. Not only must the telescope have had extraordinarily good definition, the air also must have been unusually clear and free of tremor. But this distinctness is not confined to the actual ship, it is also exhibited in the unusual images in each of which even the ratlins between the shrouds are seen; that is to say the stratification of the air must have been so exquisitely arranged and so undisturbed by fluctuations that horizontal lines not an inch in diameter appeared distinct and crisp at the distance of 14 miles.

Now if the stratification had been in concentric layers the curvature of these would necessarily have caused great distortion in the images, for that curvature bears a large proportion to the angular extent of the object. To produce, by any possible arrangement of strata, an undistorted image, that arrangement must be plane. Here we are face to face with another inconceivable state of the atmosphere; the physical explanation bristles with impossibilities.

Although there be no details in measurement, Mr. Vince has favoured us with important details in construction. This drawing shows, in the first place, the top-mast and parts of the rigging of a sloop with the mainsail and jib well filled by the breeze; the foresail is not set; we must infer that the craft was making way enough without it. Here the end of the gaff is connected to the top-mast by an elegantly curved line, reproduced in the images. In an actual sloop under sail, the gaff is held up by a strong tackle, which has to carry the weight of the mainsail, and to resist the tension caused by the wind. The resulting strain on the top-mast if the arrangement were as in the drawing, would be too great for that spar, and appropriate fore-stays would be needed. This part of the drawing is not a representation of reality.

The exceeding clearness of the two images is remarkable; daylight is seen between the mainsail and the mast in the intervals of the reeving rings; the wind must have been strong. The end of the boom is connected to the stern of the vessel by a loose line; yet the duty of this line is to resist the pressure of the wind upon the mainsail, keeping that sail to the proper inclination. Again the pressure of the mainsail, and the pull of the foresail and jib tend to break the mast; this pressure is usually resisted by the shrouds, which, for that purpose, are placed abaft the mast. No sloop, nor indeed any other craft was ever rigged with the shrouds before the mast, as is seen in these images; the arrangement is nonsensical. Yet again, the jib is shown as if it were reeved to the fore-stay. If this were actually done the sail, being in the ship's mesial plane, could be of no service for propulsion; it could only keep the ship's head from the wind. The lower edge of the jib is shown curved away from the bowsprit as it should be, but the sheet is hauled close to the stem. More than all this, the ship should have a rudder, the rudder should have a tiller, and at the end of the tiller there should be the steersman, who, standing between the spectator and the main-sail, should have been a conspicuous object on board. Judging from the other minutiæ we should have been able to recognise the articles of his dress. But neither helm nor steersman is to be seen.

This drawing does not represent any thing that was seen through the telescope.

While attending to the ship, we have been forgetting the sea on which it floats. The rays forming the images in the air must have passed at heights of from 40 to 70 feet above what appears as the edge of the horizon; they must have been representations of the vessel as seen from these heights. Now, from a height of 70 feet the visible horizon is 10 miles off; that is 2½ miles beyond the sloop; therefore each of the images should have been accompanied by a horizon; of these, however, there is no trace.

The intricacy of the arrangement of strata needed, within these narrow limits, to have produced with such wonderful clearness, both an inverted and an erect image, needs only to be mentioned.

From whatever point of view we regard the matter, we find inaccuracy, incongruity, impossibility; the psychological aspects of the narrative being identic with those of the vision of Dover Castle seen eight years later. In each case there is the palpable substitution of an ideal picture for the supposed reality; in each case the technical explanation is opposed to the narrative itself as well as to the known physical laws; it being noteworthy that, in both, the concealed part of the object is represented as always visible; and in such case the obvious absurdity of the substitutions shows clearly the absence of any conscious intention to deceive. Mr. Vince has told, in perfect good faith, the impressions on his own mind; impressions so strong as to have shut out every consideration of probability or of possibility, and to have completely overpowered his better judgment. The mastery over his mind, acquired by this delusion, is well exemplified by the proposal seriously made, that, on the recurrence of such a phenomenon, a ship be sent out provided with barometers on deck and at the mast head, to ascertain the difference of pressure. He expected wind enough to carry the ship to sea, forgetting that perfect calm is essential to the stratification; he forgot too that no then existing barometer could be accurately read on ship-board.

The dominant idea was in both cases that of the great curvature of the rays of light. In his *Complete System of Astronomy*, 1823, Vince shows that the curvature is only one-seventh part of the curvature of the earth. It is pleasant to think that these early occasional illusions had passed away, to leave his mind clear for the performance of such great and good work in furtherance of Astronomical Science.

5. On a Case of Dyspeptic Vertigo.

By Professor Crum Brown.

The dyspepsia was, as far as I know, of a very ordinary kind. It began with loss of appetite, discomfort after meals, and general sense of weakness and uselessness. Then came a crisis. Waking in the middle of the night with pain and nausea, an hour or two of this, thorough evacuation of the stomach, great discomfort next day, and then no symptom of any thing wrong as long as I adhered to the diet which experience soon led me to, viz., very simple food and very little of it. To this I adhered for about four weeks. Now and then, perhaps three times altogether, feeling quite well, I ventured to eat like other people, and was at once taught by abdominal pain and diarrhœa, that I must still consider myself an invalid, or at best a convalescent. After about four weeks I found that I could venture on a chop or a potato, and gradually felt my way back to the usual diet. In all this there is nothing I suppose at all uncommon. It is the first time I experienced any thing of the kind, but I have no doubt others have often gone through the same or worse, and my dyspepsia can have no sort of interest in itself to a physician.

Accompanying the dyspepsia there was, however, a symptom, which may be common, but which, as far as I know, has not been described, at all events does not seem to have been felt by any one sufficiently interested in physiology to lead him to make careful observations on it. This was a very well-marked but not very violent vertigo. This symptom did not make its appearance at first,—in fact, it was two days after what I have called the crisis before any trace of vertigo appeared. I was nearly quite well, though of course my wellness depended on my adherence to the sparing indulgence in beef tea and custard pudding, when I first felt the vertigo.

Walking along the street, my attention was suddenly called to a dog at the side of the pavement, and I turned my head sharply to the left side and downwards, to look at him. I immediately felt a very distinct attack of vertigo, and it was with some effort that I preserved my equilibrium. I walked home without the least difficulty, as the vertigo passed off very quickly, and I found that if I avoided sudden movements of the head I could keep clear of such attacks. All that remained was a feeling of constraint and want of confidence. The same evening, after putting out the gas in the lobby and staircase, I was going to bed when I found I had to go downstairs again, having forgotten something or other. I ran down without thinking of the vertigo, and when I reached the foot of the stair was much surprised by what I saw. Above my front door there is, as there is in most Edinburgh houses, an oblong pane of glass, and when the house is in darkness, the light from the lamps in the street shines in by this window. Now what I saw was an oblong illuminated area, not with horizontal and vertical sides, but inclined so that its long sides made an angle, as far as my recollection enables me to estimate it, of about 20° at least with the horizontal. While wondering what this could be, I suddenly saw that it must be the window, and the instant this idea occurred to me, it in a moment regained its right position. All this did not take half a minute. I went to bed and slept soundly, as indeed I always did through the whole course of the illness, except on the two or three occasions when an attempt to return to ordinary diet produced a disturbance of the digestive organs. Next morning, on getting out of bed, I found that that movement of the body had produced a vertigo much more severe, and lasting a much longer time than either of those of the day before, and although it passed away on my remaining quiet for some time, every attempt to move set it up again. I accordingly went back to bed, and after lying quiet for a few minutes felt quite well; but getting up was out of the question. To occupy myself I sent for the morning newspaper. When it arrived I was lying on my right side, facing the window. To read it comfortably I had to turn round, so that the light should fall on it. I accordingly rolled myself over, and holding out the paper tried to read it. This, however, I could not do, the letters seemed to fly across the paper, and while I could see that it was print, and could make out the size of the letters, I could not distinguish one of them. This optical vertigo was not accompanied by any feeling of nausea or of insecurity. Reflecting upon what produced it, I thought I might undo it. If I rolled round to my right side again that might put it right, but then I wished to have the window behind me. I tried while keeping my body at rest, rolling my head quickly to the right, and then slowly back again, and found that an effectual remedy, and from that time, as long as I remained in bed or on the sofa, viz., about ten days, I could always neutralise an abnormal apparent rotation, by rotating the head about the axis of the apparent rotation, quickly in one sense, and then slowly back again. The sense in which the quick rotation had to be made was that in which surrounding bodies seemed to move. The first correction was sometimes too much, sometimes not enough; in such cases a second smaller correction was easily made. Day by day the intensity and duration of the vertigo became less. Once or twice a day, I made an experiment by making a whole rotation, and lying still to observe how long the apparent motion of external things continued. At last I found that I could walk about, not without some difficulty and feeling of insecurity. This gradually diminished until a week or so before my return to ordinary food it was practically gone.

During my recovery, I frequently experimented upon the optical vertigo. These experiments were suggested by an accidental observation. Having put out the drawing-room gas one evening, as I was leaving the room I saw the reflection of outside gas lamps in the glass of a picture hanging on the drawing-room wall, and these lights seemed to me to be moving exactly as if the picture were swaying on its cord. I then turned and stood before the picture. I satisfied myself that the picture was motionless. I then made about half a rotation, that is, I turned slowly till my back was to the picture, and quickly turned and faced it. I then saw the lights move to the right or left as the case might be, the sense of the apparent rotation of the lights being the opposite of my real rotation. This experiment I frequently made to find how I was getting on, but found that I could not repeat it on real lights seen directly through the window.

Quite lately I tried whether I could produce any trace of the feelings which were so familiar to me then. By rapidly spinning round three or four times, I find that I can produce very much the same sensation which half a turn produced when I was just well enough to walk. The sensation now lasts two or three seconds, then it lasted sometimes one, sometimes more than two minutes.

It is worth noting that during the whole course of the illness there was never any disturbance or irregularity in the sense of hearing.

So far for the facts of the case. The points of interest seem to me to be:—(1) That the vertigo never occurred unless provoked by a real rotation of the head. (2) That the phenomena were perfectly symmetrical. (3) That the axis of the apparent rotation was always the same as that of the real rotation which had provoked it, while its sense was the opposite. The vertigo was in fact only a very much exaggerated form of a perfectly natural phenomenon. It might, therefore, be supposed that the morbid condition was a sort of hyperæsthesia of the sense of rotation. This, however, was not the case. The direct sensitiveness to ordinary rotations was if anything diminished, it was the after effects of rotations that were greatly increased both in intensity and in duration. (4) Visual vertigo often ceased when there was sufficient evidence that external bodies were really at rest. Thus, as soon as the illuminated rectangle was recognised as the window, the displacement of the vertical ceased, and the window was seen in its real position.

Again visual vertigo occurred when the reflexions of the gas lights in the glass of a picture frame were looked at, but not with the gas lights looked at directly.

It is unfortunate that no observation of the eyes was made during the continuance of visual vertigo, as for instance, when the printed characters seemed to fly across the newspaper. It would have been important to determine in such a case the presence or absence of *nystagmus*. It is to be hoped that any one who may fall in with a similar case will not make this omission.

The relation of *nystagmus* to visual vertigo is of great importance and interest, but it would be out of place to discuss it in a note of this kind. I hope to have an opportunity before long of dealing with it in a special paper.

PRIVATE BUSINESS.

Mr James Sorley, Mr William Thomson, M.D., B.Sc., Mr Thomas Graham Young, and Mr W. Dyce Cay, M. Inst. C.E., were balloted for, and declared duly elected Fellows of the Society.

Monday, 20*th March* 1882.

PROFESSOR DOUGLAS MACLAGAN, M.D., Vice-President, in the Chair.

The following Communications were read:—

1. Note on the Carboniferous Rocks of the South of Scotland.

By Archibald Geikie, F.R.S.

The well-known northward attenuation of the massive Carboniferous Limestone of Lancashire and Yorkshire, and the gradual replacement of its thick calcareous groups by sandstones, shales, and seams of coal, with interstratifications of marine limestone, can be advantageously studied in the southern counties of Scotland. In these districts a characteristic and recognisable base for the Carboniferous system is presented by the deep red Sandstones and marles of the Upper Old Red Sandstone, which pass up conformably into that system, but rest with a violent unconformability upon every formation older than themselves, including even the Lower Old Red Sandstone of Berwickshire and the Cheviot Hills. These red rocks contain few organic remains; but here and there they yield scales of *Holoptychius* and other fishes, which suffice to define their geological horizon. The striking unconformability of these Upper Old Red Sandstones is connected with great inequalities in the surface upon which they were deposited. In some places they swell out to a thickness of many hundred feet; but elsewhere they may be seen rapidly to die out against an underlying prominence of older rocks round which the earlier Carboniferous groups overlap. The general contours of the ground must consequently have been remarkably varied. It is possible even yet to define approximately the outlines of some of the shores of the period.

The Upper Old Red Sandstone is overlaid by a volcanic zone, consisting mainly of various porphyrite lavas, with occasional tuffs. This zone forms a marked feature in the geology of Berwickshire and Roxburghshire, running in a line of conspicuous eminences, and serving as a convenient platform to mark the base of the Carboniferous system. It can be followed from the southern edge of the Lammermuir chain to near the mouth of the Nith, and it reappears even on the west side of that river in Kirkcudbright. Associated with it are numerous "necks," marking some of the vents from which the volcanic material was ejected, and as these "necks" occur among Silurian hills, at some distance from the present edge of the porphyrites, it is evident that these latter once covered a much wider area, from which, together with much of the overlying Carboniferous rocks, they have been denuded. The volcanic rocks in the south of Scotland agree in general character with those which occupy a similar geological position in Ayrshire, Renfrewshire, Dumbartonshire, and Stirlingshire, and both are probably referable to the same period in the volcanic history of the country. In the Eskdale district the porphyrite band consists of one or two separate flows, with an aggregate thickness of from 40 to 100 feet.

From the top of the volcanic zone the Carboniferous system may be followed in many excellent natural sections up into the Scar or Main limestone of the English Carboniferous Limestone series. In Berwickshire there is a great development of that peculiar phase of the Lower Carboniferous rocks to which the name of "Cement-stone group" has been given by the Geological Survey of Scotland. The strata consist of grey, white, and yellow, less frequently reddish, sandstones, with blue, grey, and greenish shales and clays, bands and nodules of cement-stone or impure limestone, and occasional veinings of gypsum. On the west side of the Cheviot Hills, which must have stood up as an important geographical boundary in early Carboniferous times, this "cement-stone" type of sedimentation also occurs but less extensively, and with a curious blending of characters lithological and palæontological, which give to the basin of Eskdale and Liddesdale an exceptional geological interest.

In this district the following general section in descending order is observable:—

General Section of the Carboniferous Rocks of Eskdale and Liddesdale.

		Feet.
	Scar (Scaur) Limestone of Northumberland.	
11.	Fell Sandstones probably more than	1000
10.	Horizon of Plashetts and Lewisburn coals,	
9.	Upper cement-stone group,	about 300 to 400
8.	Horizon of Canobie coals,	800
7.	Gilnockie (marine) limestone group,	400 or 500
6.	Zone of volcanic tuff,	10 to 20
5.	Scorpion Shales,	50
4.	Zone of volcanic tuff and porphyrite,	50 to 100
3.	Sandstones of Irvine Burn,	200
2.	Lower cement-stone group (Tarras),	200 to 300
1.	Whita Hill Sandstone,	500 to 600
	Volcanic band (Porphyrites, &c.),	40 to 100
	Upper Old Red Sandstone lying uncomformably or Upper Silurian rocks,	300

A few remarks may be offered upon the characters of these successive platforms.

1. The White Sandstone, well seen on Whita Hill above Langholm, consists chiefly of massive beds of hard white, yellow, and pinkish calcareous sandstones, often full of concretions ("galls") of a pale clay, which dropping out gave a honeycombed aspect to weathered surfaces. The sandstones are sometimes separated by thin shale partings, and occasional seams of impure limestone or cement-stone.

2. In the Tarras water a lower group, of true "cement-stone" facies, attains a thickness of probably from 200 to 300 feet. It consists of blue clays and shales with impure limestone or cement-stones and beds of shaly sandstone. These strata have yielded numerous remains of fishes, eurypterids and ostracods, but none of the ordinary marine organisms of the Carboniferous limestone bands.

3. This lower cement-stone group is overlaid by a set of sandstones, chiefly coarse brown and friable, with pebbles of white vein-quartz. These strata become more fossile towards the top, and contain courses of shale and bands of cement-stone.

4. A second volcanic platform appears on this horizon. It consists sometimes of slaggy porphyrite, evidently a contemporaneous outflow, and sometimes of a fine volcanic tuff. It can be followed for some distance from the valley of the Esk up Liddesdale. With it and a still higher volcanic zone should be associated the "necks" by which the older Carboniferous rocks of the district are pierced, and which no doubt represent some of the volcanic vents of the time. At the top of the tuffs comes a band of black cherts, which may perhaps be referable to the deposit of some thermal siliceous springs connected with the volcanic eruptions.

5. This zone of fine grey shale, about 50 feet thick, is that which has yielded the remarkable series of fossils already described, and from which others since obtained have now to be brought to the notice of the Society. In the lower and central parts of the zone there occur numerous specimens of undoubtedly marine organisms, such as *Orthoceras*, *Aviculopecten*, *Myalina*, *Lingula*, *Discina* and *Palechinus*. With these are mingled remains of fishes, crustacean and scorpions. Mr. Peach has observed, however, that towards the upper part of the bed where plants occur in some quantity, most of the Scorpions, Eurypterids, and Limuli have been discovered.

6. A third zone of volcanic tuff 10 to 20 feet thick overlies the Fossiliferous or Scorpion Shales. This is the highest platform on which contemporaneous volcanic action has been observed in this part of Scotland.

7. Above the third volcanic platform we enter upon a totally distinct type of strata—sandstones and shales with several bands of true crinoidal limestone, exactly like those of the ordinary Carboniferous Limestone, and containing many of the same fossils. These limestones form conspicuous features in the Esk below Canobie and at Penton Linns. One of them is 30 or 40 feet thick. Associated with them are seams of coal exactly as in the lower part of the Carboniferous limestone series of central Scotland. One of the most interesting features in this marine group is the evidence that it dies out towards the north-east in Liddesdale; while, on the other hand, it increases in thickness towards the

south-west. In Liddesdale, therefore, the lower and upper cement-stone groups form one continuous series, with no intervening zones of marine limestone. The open sea must have stretched towards the south and west, while the land lay to the north, traces of its margin being still recognisable about the flank of Carter Fell.

8. The Canobie Coal group comprises a series of strata about 800 feet thick, containing thirteen coal-seams, which include an aggregate thickness of 39 feet of coal. The lower seams are intercalated with marine limestones, so that their low position in the Carboniferous series admits of no doubt. It is remarkable, however, that the plants associated with these coals are true Coal-measure forms, as determined by Mr. R. Kidston. The Canobie group is overlaid by reddened sandstones lying below the Permian (St. Bees) sandstones, which cover them unconformably. It is therefore impossible to follow the upward section further in the Esk valley. In Liddesdale, however, the Canobie coals may be traced running towards the north-east, and becoming much attenuated in their progress. They dip below the upper cement-stone group No. 9.

9. Over the horizon of the Canobie coals in Liddesdale comes a group of blue shales and cement-stones, with several thick bands of sandstone and seams of coal on different horizons. Those beds present this ordinary "cement-stone" facies of the upper division of the Scottish Calciferous sandstones.

10. The Plashetts and Lewisburn coal lie above the cement-stone group No. 9.

11. The southern margin of Liddesdale is marked by a conspicuous group of sandstone, of which the bottom beds cap the eminence of the Larriston Fells, and likewise rise into Peel Fell. The name of "Fell Sandstones" has been given to them. They must vary much in thickness, owing to the very lenticular character of their individual beds. In Liddesdale they may be 1000 feet thick. They cover a large area in Northumberland, and form a well-marked geological group lying immediately below the Main or Scar limestone, where the ordinary phase of the Carboniferous limestone reappears.

It is evident that the central part of the thick cement-stone groups of Upper Liddesdale lies on the same horizon as the marine zone of Gilnockie below Langholm. There can be little doubt that the Scottish cement-stone series generally is a less thoroughly marine representative of the lower part of the Carboniferous Limestone of England.

2. Additional Contributions to our Knowledge of the Fossil Fishes of Eskdale and Liddesdale. By Dr. R. H. Traquair.

3. Further Researches among the Crustacea and Scorpions of the Carboniferous Rocks of the Scottish Border. By Mr. B. N. Peach.

4. Report on the Fossil Plants collected by the Geological Survey of Scotland in Eskdale and Liddesdale. By Robert Kidston.

(*Abstract.*)

Through the kindness of Professor Geikie, Director-General of the Geological Survey of Great Britain, I have had the pleasure of examining the fossil plants collected by the Scottish Geological Survey in Eskdale and Liddesdale.

The collection contains about four hundred and fifty specimens, a number of which, however, were too imperfect for further identification than that of the genus.

Eight of the plants I believe to be new species, and a few of the others, as far as I am aware, are now recorded for the first time as occurring in Scottish rocks.

The following is a list of the genera and species; those I consider to be new to science are marked with an asterisk:—

PLANTS FROM ESKDALE AND LIDDESDALE.

(*Calciferous Sandstone Series.*)

THALLOPHYTA.

ALGÆ.

1.* *Chondrites plumosa*, Kidst.
2.* *simplex*, Kidst.
3.* *Crossochorda carbonaria*, Kidst.
4.* *Bythotrephis*, sp.

FILICACEÆ.

SPHENOPTERIDEÆ.

5. *Sphenopteris linearis*, Brong.
6. *furcata*, Brong.

7.* *Sphenopteris Geikiei*, Kidst.
8. *bifida*, L. & H.
9. *excelsa*, L. & H.
10. *Hibberti*, var. L. & H.
11. *Höninghausi*, Brong.
12.* *decomposita*, Kidst.
13. sp.
14. *Staphylopteris Peachii*, Carr.
15. *Eremopteris* (*Sphenopteris*) *erosa* (?) Morris.
16.* *Macconochii*, Kidst.
17. *Rhacophyllum Lactuca*, Sternb.

PALÆOPTERIDEÆ.

18. *Adiantites Lindseæformis*, Bunbury.

NEUROPTERIDEÆ.

19. *Neuropteris cordata*, Brong.
20. (*Cyclopteris*) *Trichomanoides* (?), Brong.

STIPES FILICINÆ.

21.* *Caulopteris minuta*, Kidst.

EQUISETACEÆ.

22. *Volkmannia*, sp.

LYCOPODIACEÆ.

23. *Lepidodendron Sternbergii*, Brong.
24. sp.
25. *Lepidostrobus variabilis*, L. & H.
26.* *fimbriatus*, Kidst.
27. *Lepidophyllum lanceolatum*, L. & H.
28. *Lycopodiaceous sporangia.*
29. *Cordaites*, sp.
30. *Stigmaria ficoides*, Brong.

FRUITS.

31. *Cardiocarpus apiculatus*, Göpp. & Berger.
32. sp.
33. *Schutzia*, sp.

PLANTS FROM CANONBIE.

FILICACEÆ.

SPHENOPTERIDEÆ.

1. *Sphenopteris multifida*, L. & H.
2. *obtusiloba* (?), Brong

3. *Sphenopteris*, sp.
4. *Staphylopteris*, sp.

NEUROPTERIDEÆ.

5. *Neuropteris heterophylla*, Brong.

ALETHOPTERIDEÆ.

6. *Alethopteris heterophylla*, Sternb.

PECOPTERIDEÆ.

7. *Pecopteris nervosa*, Göpp.
8. sp.

EQUISETACEÆ.

9. *Calamites*, sp.

LYCOPODIACEÆ.

10. *Lepidodendron*, sp.
11. *Lepidophyllum lanceolatum*, L. & H.

In comparing the first part of the list of the species in this collection with the fossil plants from the Calciferous Sandstone Series in the neighbourhood of Edinburgh, their similarity will be at once apparent.

This is remarkable when viewed in relation to the fish and crustacean remains which have been already described from Eskdale and Liddesdale by Dr. R. H. Traquair, and Mr. B. N. Peach, which, as far as at present known, are mostly peculiar to these districts.

This points to some local physical conditions, which, though favourable for the growth of plants widely distributed in other parts of Scotland, seem to have favoured the existence of a fauna peculiar to itself.

P.S. 28th July 1882.—Since compiling the above list, a few more specimens have been handed to me for examination. Among them were the two following, which must now be added :—

ALGÆ.

34. *Chondrites Targionii*, Brong.

INCERTÆ SEDIS.

35. *Pothocites*, sp.

5. On the Formation of Serpentine from Dolomite. By J. J. Dobbie, M.A., D.Sc., Assistant to the Professor of Chemistry, University of Glasgow, and G. G. Henderson, B.Sc.

Some time since, specimens of a peculiar-looking rock, found at Fintry, in the Campsie district, were put into our hands for analysis. The specimens were of a light chocolate-brown colour, and apparently homogeneous. They were somewhat harder than ordinary limestone, had a waxy lustre, and broke with a sharp-edged splintery fracture, translucent upon the thin edges. With hydrochloric acid they effervesced slowly, at the same time gelatinising. The specimens were weathered white to a considerable depth.

Analysis proved that the specimens were composed principally of lime, magnesia, silica, carbonic acid, and water, and that, notwithstanding their homogeneous appearance, they varied considerably in composition. Analysis numbers I. and II., each of which was repeated several times, represent the limits of this variation.

I.		II.	
SiO_2	18·50	SiO_2	22·03
Fe_2O_3	2·67	Fe_2O_3 } Al_2O_3 }	5·90
Al_2O_3	4·63		
CaO	25·39	CaO	24·01
MgO	23·65	MgO	19·53
CO_2	10·95	CO_2	3·20
H_2O	14·10	H_2O	25·23
	99·89		99·90

It will be observed that in No. I. the amount of water is much less and the amount of carbonic acid much greater than in No. II. The composition of the specimens was thus shown to be intermediate between that of dolomite and of a hydrated silicate of lime and magnesia, since, the carbonic acid being insufficient to combine even with all the lime, the remainder of the lime and the magnesia must have been combined with the silica.

We were at once struck by the similarity between our specimens and certain serpentines occurring at Oxford, Canada (Zirkel, *Petrographie*, i. 324), and described by Sterry Hunt as composed of a mixture of serpentine with carbonate of lime and magnesia. One of these serpentines contained 10 per cent. of carbonate of lime with a small percentage of carbonate of magnesia, another was a mixture in almost equal proportions of serpentine and dolomite.

We had been led to believe that the specimens given us for analysis had been found *in situ*, but on inquiring particularly we discovered that they had been broken from some masses lying near a lime-kiln, and in short that they were pieces of the ordinary dolomitic limestone of the district, which had been partially burned in the kiln, and subsequently hydrated by exposure to the weather.

We made careful analyses of the unaltered limestone with the view of ascertaining the precise nature of the change undergone by our specimens. The following numbers may be taken as fairly representing its average composition :—

SiO_2	9·22
Fe_2O_3 Al_2O_3	3·57
CaO	27·78
MgO	18·25
CO_2	40·90
	90·72

Comparing this analysis with those given above of the altered limestone, it will be at once obvious that the difference in composition is exactly of the nature which we should have expected. In one case the carbonic acid has been almost entirely driven off, and in the other case the percentage has been reduced from 40 to 10. In other words, the silica originally present in the impure dolomite has, at the high temperature of the kiln, displaced the carbonic acid and combined with the bases. The carbonic acid in the altered limestone is, as already pointed out, insufficient to combine with all the lime, and, as we shall immediately show, there is good reason for believing that all the remaining carbonic acid is in combination with the lime, and all the magnesia and part of the lime in combination with the silica. If by any means the carbonate of lime could be separated from the silicate, the remainder would be a tolerably pure hydrated silicate of magnesia, Now the removal of the carbonate of lime from silicate of magnesia admits of easy explanation, on the supposition that the action whereby dolomite limestone is converted into serpentine is, as Mr. James Geikie long ago suggested (*Quart. Jour. Geol. Soc.*, 1866, p. 533), a hydrothermal action.

Many theories have been advanced to account for the formation of serpentine. Petrologists are nearly all agreed in attributing to it in all cases a metamorphic origin. There is, however, some diversity of opinion, as to whether it has in every instance been derived from volcanic rocks by the alteration of magnesian minerals, or whether in certain cases it ought not rather to be regarded as a product of the metamorphism of sedimentary rocks. Of its origin in many cases from volcanic rocks rich in magnesia there cannot be the slightest doubt.

So long ago as 1835, Quenstedt (Pogg., *Ann.* 1835, xxxvi. 370) showed that the celebrated serpentine crystals of Snarum, in South Norway, were in reality pseudomorphs of serpentine after olivine, and though his views were not universally accepted at the time, they have since been fully confirmed both by mineralogists and by chemists. Gustav Rose (Pogg., *Ann.* 1851, lxxxii. 511) showed, from the chemical point of view, that olivine would by a slight alteration in its composition pass readily into serpentine; and since his time numerous microscopists have demonstrated that the olivine of many basalts is in process of undergoing this change. The theory of the alteration of volcanic rocks rich in magnesian minerals into serpentine, affords a satisfactory explanation of its occurrence in veins and dykes. But, on the other hand, its frequent occurrence in beds interstratified with limestone, dolomite, and occasionally schists, would seem to indicate in these cases a different origin. Rose, in the paper already cited, expresses the opinion with regard to serpentine in dolomite, occurring in crystalline schistose rocks in Silesia, that it has been formed by the alteration of the dolomite. Sterry Hunt attributes a similar origin to the serpentines of the Laurentian series in Canada (*Phil. Mag.*, 1857, xiv. 388). Volger (*Entwickelungsgeschichte der Mineralien der Talc-glimmer Familie*) adopts the same view, and more recently Mr. James Geikie has applied this theory to explain the formation of the serpentine of Carrick in Ayrshire (*loc. cit.*).

Both on stratigraphical and chemical grounds, the conversion of dolomitic limestone into serpentine seems probable, but, so far as we are aware, no one has as yet pointed out the precise nature of the reactions involved in this change.

Carbonate of magnesia decomposes at a much lower temperature than carbonate of lime, the difference between the decomposing points being so great that it is practically made use of in Pattinson's process for the preparation of magnesia from the magnesian limestone of Durham. The limestone is calcined in close iron vessels at a dull red heat, the carbonate of magnesia alone undergoing decomposition at this temperature (*Pharmaceutical Journal*, 1844, iii. 424). Now it is easy to understand that if a rock, such as the Campsie limestone, containing carbonate of lime, carbonate of magnesia and silica, were heated to a temperature sufficient to decompose the carbonate of magnesia, but not the carbonate of lime, the magnesia at the moment of liberation would combine with the silica, forming silicate of magnesia. Adopting the theory of hydrothermal action, the carbonic acid set free from the magnesia would be taken up by water, and would act as a solvent upon the carbonate of lime, removing it, and leaving behind hydrated silicate of magnesia only.

That the carbonate of lime has not been removed from the specimens of the Campsie limestone which had passed through the kiln, is simply due to the fact that there was no water present to take up the carbonic acid. We do not mean, of course, to assert that in every instance this has been the character of the change, whereby dolomite has been altered to serpentine, but in the case of impure dolomites containing sand, the explanation is more satisfactory than Sterry Hunt's somewhat vague theory of the action of heated solutions of alkaline silicates.

The theory which we have briefly sketched seems to reconcile satisfactorily many of the facts connected with the composition and occurrence of serpentine. It explains—

(1) The peculiar composition of such serpentines as those of Canada, and the frequent occurrence of carbonate of lime and carbonate of magnesia in the serpentine of other localities (Zirkel, i. 324).

(2) The occurrence of serpentine in beds interstratified with sedimentary rocks.

(3) The frequent association of serpentine with dolomite and limestone. In these cases in which dolomite contains the requisite amount of silica, all the magnesia would be converted into serpentine, and it would be found associated with limestone only.

(4) Its association with schists, which were probably altered from the clays and sandstones interstratified with the dolomite, by the same agencies as those which converted the dolomite into serpentine.

In conclusion, we may state that we are engaged in making experiments upon the direct conversion of the Campsie limestone into serpentine, and upon the influence exercised by one carbonate upon the decomposing point of another, with which it is mixed.

Monday, 3rd April 1882.

PROFESSOR BALFOUR, M.D., Vice-President,
in the Chair.

The following Communications were read:—

1. On the Figures of Equilibrium of a Rotating Mass of Fluid.

By Sir William Thomson.

(*a*) The oblate ellipsoid of revolution is proved in Thomson and Tait's *Natural Philosophy* (first edition, § 776, and the Table of § 772) to be stable, if the condition of being an ellipsoid of revolution be imposed. It is obviously not stable for very great eccentricities without this double condition of being both a figure of revolution and ellipsoidal.

(*b*) If the condition of being a figure of revolution is imposed, without the condition of being an ellipsoid, there is, for large enough moment of momentum, an annular figure of equilibrium which is stable, and an ellipsoidal figure which is unstable. It is probable, that for moment of momentum greater than one definite limit and less than another, there is just one *annular* figure of equilibrium, consisting of a *single ring*.

(*c*) For sufficiently large moment of momentum it is certain that the liquid may be in equilibrium in the shape of two, three, four, or more separate rings, with its mass distributed among them in arbitrary portions, all rotating with one angular velocity, like parts of a rigid body. It does not seem probable that the kinetic equilibrium in any such case can be stable.

(*d*) The condition of being a figure of equilibrium being still imposed, the single-ring figure, when annular equilibrium is possible at all, is probably stable. It is certainly stable for very large values of the moment of momentum.

(*e*) On the other hand, let the condition of being ellipsoidal be imposed, but not the condition of being a figure of revolution. It is proved in Thomson & Tait's *Natural Philosophy*, that whatever be the moment of momentum, there is one, and only one, revolutional figure of equilibrium.

I now* find that,

(1) The equilibrium in the revolutional figure is stable, or unstable, according as $f\left(=\frac{\sqrt{a^2-c^2}}{c}\right)$ is $<$ or $>$ 1·39457.

(2) When the moment of momentum is less than that which makes $f = 1·39457$ (or eccentricity = ·812663) for the revolutional figure, this figure is not only stable, but unique.

(3) When the moment of momentum is greater than that which makes $f = 1·39457$ for the revolutional figure, there is, besides the unstable revolutional figure, the Jacobian figure with three unequal axes, *which is always stable if the condition of being ellipsoidal is imposed.* But, as will be seen in (*f*) below, the Jacobian figure, without the constraint to ellipsoidal figure, is in some cases certainly unstable, though it seems probable that in other cases it is stable without any constraint.

(*f*) Referring to Thomson & Tait's *Natural Philosophy*, § 778, and choosing the case of a a great multiple of b, we see obviously that the excess of b above c must in this case be very small in comparison with c. Thus we have a very slender ellipsoid, long in the direction of a, and approximately a prolate figure of revolution relatively to this long a-axis, which, revolving with proper augular velocity round its shortest axis c, is a figure of equilibrium. The motion so constituted, which, without any constraint, is a configuration of minimum energy or of minimax energy or of maximum energy, for given moment of momentum, is a configuration of *minimum* energy for given moment of momentum, *subject to the condition that the shape is constrainedly an ellipsoid.* From this proposition, which is easily verified, in the light of § 778 of Thomson & Tait's *Natural Philosophy*, I infer that, with the ellipsoidal constraint, the equilibrium is stable. The revolutional ellipsoid of equilibrium, with the same moment of momentum, is a very flat oblate spheroid; for it the energy is a minimax, because clearly it is the smallest energy that a revolutional ellipsoid with the same moment of momentum can have, but it is greater than the energy of the Jacobian figure with the same moment of momentum.

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* Proof of these results, (1), (2), and (3) will be found in the forthcoming new edition of Thomson & Tait's *Natural Philosophy*, vol. i. part ii.

(*g*) If the condition of being ellipsoidal is removed and the liquid left perfectly free, it is clear that the slender Jacobian ellipsoid of (*f*) is not stable, because a deviation from ellipsoidal figure in the way of thinning it in the middle and thickening it towards its ends, or of thickening it in the middle and thinning it towards it ends, would with the same moment of momentum give less energy. With so great a moment of momentum as to give an exceedingly slender Jacobian ellipsoid, it is clear that another possible figure of equilibrium is, two detached approximately spherical masses, rotating (as if parts of a solid) round an axis through their centre of inertia, and that this figure is stable. It is also clear that there may be an infinite number of such stable figures, with different proportions of the liquid in the two detached masses. With the same moment of momentum there are also configurations of equilibrium with the liquid in divers proportions in more than two detached approximately spherical masses.

(*h*) No configuration in more than two detached masses, has secular stability according to the definition of (*k*) below, and it is doubtful whether any of them, even if undisturbed by viscous influences, could have true kinetic stability; at all events, unless approaching to the case of the three material points proved stable by Gascheau (see Routh's *Rigid Dynamics*, § 475, p. 381).

(*i*) The transition from the stable kinetic equilibrium of a liquid mass in two equal or unequal portions, so far asunder that each is approximately spherical, but disturbed to slightly prolate figures (according to the well-known investigation of equilibrium tides, given in Thomson & Tait's *Natural Philosophy*, § 804), and to the more prolate figures which would result from subtraction of energy without change of moment of momentum, carried so far that the prolate figures, now not even approximately elliptic, cease to be stable, is peculiarly interesting. We have a most interesting gap between the unstable Jacobian ellipsoid when too slender for stability, and the case of smallest moment of momentum consistent with stability in two equal detached portions. The consideration of how to fill up this gap with intermediate figures is a most attractive question, towards answering which I at present can offer no contribution.

(*j*) When the energy with given moment of momentum is either a minimum or a maximum, the kinetic equilibrium is clearly stable, if the liquid is perfectly inviscid. It seems probable that it is essentially unstable when the energy is a minimax; but I do not know that this proposition has been ever proved.

(*k*) If there be any viscosity, however slight, in the liquid, or if there be any imperfectly elastic solid, however small, floating on it or sunk within it, the equilibrium in any case of energy either a minimax or a maximum cannot be secularly stable; and the only secularly stable configurations are those in which the energy is a minimum with given moment of momentum. It is not known for certain whether with given moment of momentum there can be more than one secularly stable configuration of equilibrium of a viscous fluid, in one continuous mass, but it seems to me probable that there is only one.

2. Notes on Atmospheric Electricity. By C. Michie Smith.

Before leaving for India, in the end of 1876, it occurred to me that, as almost nothing seemed to be known about atmospheric electricity in the tropics, it would be well if I could take with me the apparatus necessary for making observations on it. I accordingly communicated with Sir William Thomson, who kindly obtained for me a grant from the British Association, for a portable electrometer. This instrument I took with me, and the following are the results of the observations made with it.

During the voyage a number of observations were made, but of these only two sets were of any special interest. The first of these was made in the Suez Canal, on Dec. 22nd. At 8 a.m., at noon, and again at 8 p.m. the readings showed a negative electrification of from three to eight divisions on the scale, the weather being entered as "fine and bright" and the wind as "S., very light," "E. by S., light breeze," and "E.S.E., light," respectively; while readings taken at 1.30 p.m. and 7.30 p.m. gave a positive electrification of eight divisions on each occasion. This has considerable interest in connection with some observations made in Madras.

The other set was made in the Red Sea, during a rather violent squall. In this case the readings varied very rapidly, from strong negative to strong positive, the readings an hour and a half before having been + 18 divisions. The variations took place so rapidly that no quantitative observations could be made, and in a few minutes, when the squall had passed over, the readings were found to be much as before, viz., + 17 divisions.

In Madras, a series of observations were made, extending from 17th Jan. to 4th March 1877. These were made at 8.30 a.m. and 6 p.m. and showed a wonderfully steady state of electrification, varying from a maximum of + 53 to + 19, with an average of3 + 3. The morning and evening readings usually agreed very closely. In every case the electrification was positive, and the weather was fine without any rain.

During this time the electrometer had to be recharged every two or three days, an operation which, though very simple in this climate, is by no means so simple in a climate so moist as that of Madras. After a time, I found it impossible to continue the observations at all, and sent the instrument home, to see if it could be in any way modified so as to suit the climate. On its return after a long delay, I found it leaked as badly as before, and so rendered observations almost impossible. The reason is doubtless to be found in the circumstance, that the air of Madras is not only moist, but is also very full of small particles of salt, which are constantly being carried from the surf by the sea breeze. The glass of the jar soon gets coated with these particles, and no amount of simple drying will then make the insulation good. That the fault did not lie in the jar itself I have tested since my return to this country, for I find that here the leakage is less than 1·5 per cent. per diem, while in Madras it was often over 30 per cent. per diem.

On account of these difficulties, I was unable to make any long series of observations, but in July of last year (1881) I made a few, that were specially interesting as being the only ones in which I have observed negative electrification in Madras, except during thunderstorms.

The observations were as follows :—

July				Reading.	
5	1 P.M.	Strong land wind,	Temp. 94° F.	−74	In each case there were local showers within 3 or 4 hours.
6	,,	,,	,,	−16	
7	,,	,,	,,	0	
7	2.20	,,	,,	−15	

These observations are, of course, too few to found any theory upon, but those who are acquainted with the peculiar sensations produced by the land wind in Madras, will feel that the point is worth investigation, and I hope on my return to Madras to be able to take with me improved apparatus, with which to continue the observations.

3. Recent Tests of Swan's Lamp for Fall of Resistance, with increase of Electromotive Force, and Ratio of Candle-power to Work expended. By Mr. A. Jamieson. Communicated by Professor Chrystal.

4. Communication of Preliminary Observations made by the Committee appointed by the Highland and Agricultural Society to investigate the Nature and Causes of the Sheep Diseases known as Louping-ill and Braxy.

The two diseases have been long known in Scotland, and are the cause of serious loss to stock owners. Well-informed breeders have estimated the loss at not less than half a million sterling annually.

They resemble each other in being peculiar to certain districts, and in prevailing at certain seasons of the year. Louping-ill is most frequently met with in the southern and western counties, and chiefly affects sheep feeding on rough hill pastures. It occurs during May and early in June, and is most fatal amongst lambs, but old sheep, cattle, pigs, and even poultry are liable to it. A few sporadic cases are met with in October, especially in the Western Highlands, where it is known under the name of *trembling*. Braxy, known also as inflammation and *sickness*, is more general in its occurrence, and affects high and low pastures alike. It is more or less prevalent from October till February, and attacks sheep in good condition. There is thus a summer and a winter visitation, and when these occur in the same district the mortality is often very great, sometimes carrying off nearly half of the stock. In the year 1878 the Teviotdale Farmers' Club began to investigate the nature and causes of louping-ill, and collected a considerable amount of information derived from stock owners, shepherds, veterinary surgeons, and others interested in the subject. They also employed Mr. Brotherston of Kelso to make an examination of pastures where the disease prevailed, and published the results obtained in the form of a pamphlet.

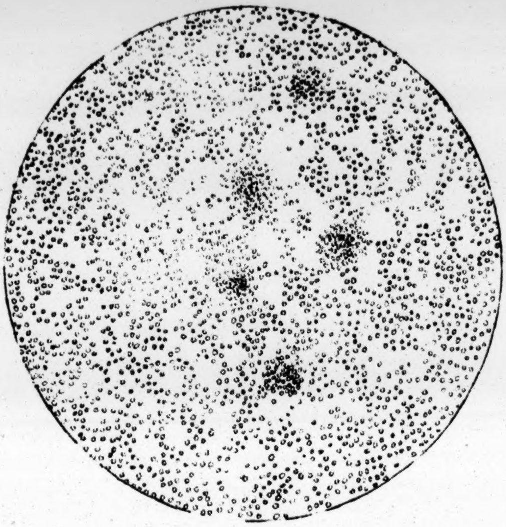
These results showed that nothing very precise was known regarding the nature of the disease, and that the causes ascribed to it were very various. The general causes were said to be cold wet weather, and especially the prevalence of east wind, poverty after the privations of severe winter, the eating of rough decayed grass just before the young grass had become plentiful enough to give a full bite, the sudden transition from old to young grass and other causes.

The result of Mr. Brotherston's investigation led him to think that the disease was caused by ergot and other fungi, which he found growing very generally upon the old withered grasses. Another special cause assigned was the bites of ticks, which are said to be invariably found on sheep affected with louping-ill. Experiments were made to test the ergot theory, but they led to no positive result. In the spring of 1881 the Highland and Agricultural Society was asked to take up the investigation, and it at once appointed a Committee, and voted a fund for the purpose.

The first thing the Committee had to do was to assure themselves that there was a special disease called louping-ill, and if so, to be able to recognise it. This was a subject of some difficulty, as the sheep and lambs which were found affected lay far and wide among the hills. As was anticipated, a considerable number of diseases were found to be grouped under the name of louping-ill. Among these Professor Williams distinguished joint-ill, navel-ill, impaction of wool in the fourth stomach of young lambs, and other inflammatory ailments incident to the lambing season, or to inclemency of weather. Besides these, however, there was found to be a special kind of disease affecting the nervous system, which had well-marked symptoms and interesting peculiarities, some of which are described in the pamphlet above mentioned. It is found to be frequently very much localised, and to attach itself to special pastures, so that a wall or partition may divide an unhealthy pasture from one in which louping-ill is unknown; and that even without any partition, one side of a hill may be healthy and the other unhealthy; and that the hirsel belonging to the one side of the hill may have many cases of louping-ill, while that belonging to the other side may be free from it, although both hirsels may meet and feed together during some hours every day. Sheep coming from a district where louping-ill is unknown, if put upon what is called louping-ill land, die off very rapidly. Stock owners are well aware of this, and when adding to their stock on louping-ill land, are careful to procure sheep from a district where the disease is known to prevail. On the other hand, cases are recorded where sheep in travelling from one sound pasture to another, having passed over a louping-ill district, have introduced the disease upon land which had previously been exempt from it. Instances are also met with where pastures seriously affected with louping-ill have been rendered healthy by means of liming and draining, and depasturing with cattle instead of with sheep for some years. There seems to be no doubt that the disease is due to something on the land and in the pasture, and the whole circumstances seemed to some of the committee to point strongly to the probability of its being a disease of an organismal kind, comparable with those which have recently been brought to light by the researches of Pasteur and other investigators. The disease is not amenable to treatment, and runs its course sometimes very rapidly. Instances are given in which sheep, apparently well, have, when startled, fallen suddenly down, and died almost immediately; and it is asserted that the number of deaths from louping-ill may be greatly increased by rough herding. It is probable that death caused in this way may be due to shock, and have nothing to do with louping-ill, for sheep are very nervous animals, and easily frightened. No cases of that kind have come under our notice. More commonly the disease comes on gradually, and the first symptoms noticed are uncertainty of gait and lameness, also loss of appetite, and consequent falling off in condition. If the case is a serious one, the next thing noticed is the inability of the sheep to rise. It struggles to do so, but has lost power in its fore or hind limbs, and lies sprawling. The head is usually thrown back, and the animal grows gradually weaker. It is seen to tremble occasionally, and its lips frequently quiver, its teeth chatter, and there is a frothy discharge from the mouth. These symptoms may continue for a week, or even a fortnight, and recovery is not impossible at almost any stage, but the proportion which recovers is very small.

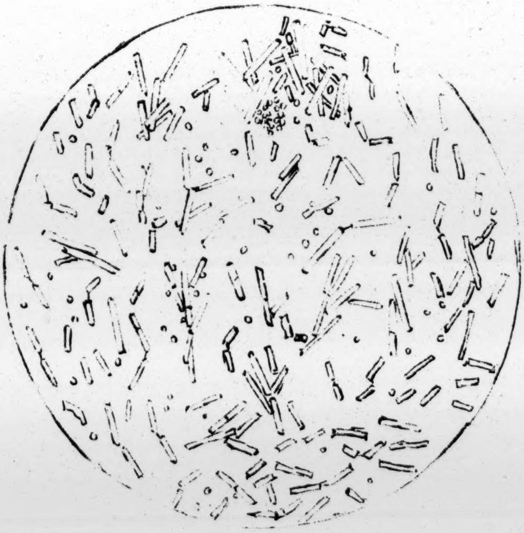
The following is Mr. Hamilton's diagnosis of a characteristic case of louping-ill, which occurred at Drynoch, in Skye. It was the case of a lamb, which had been ill for five days. It had had joint-ill in the spring, the joint had been opened under antiseptics, and the recovery was satisfactory:—

> "Found lying on right side, eyes open, no squint, pupils of medium size, struggles spasmodically when approached. If hind leg is lifted, and allowed to fall, there is no attempt at motion. If fore leg is treated in similar manner, it is moved to and fro before reaching the ground. When held up by wool of back, it moves freely, and can stand on the fore legs, but the hind feet are fixed in the ground, and there are many clonic spasms in the hind legs, which remain extended. When lying on its side, if one of the hind legs are pricked, there is a slight reflex movement, and the animal seems to feel it slightly. When the fore legs are pricked, they are immediately drawn up and retracted. When pricked on the trunk at various places, there seems to be least sensibility to pain in the hind quarters. It can move its tail. It occasionally grinds its teeth, and



X 350 Diams: No. 2

Culture obtained by inoculating mutton broth with the blood of sheep affected with louping-ill



No. 3.

X 350 Diams:

Bacilli seen in the mucous coat of the duodenum and in the peritoneal fluid of sheep ill with "Sickness."

has slight shiverings. Respirations 30, pulse 104, feeble and intermittent temperature 106° Fahr.

"Hearing and sight unimpaired. Ears move freely and frequently. Nose and lips not unusually dry. It attempts to nibble grass in neighbourhood, and sprawls with the fore legs. Head drawn back. Muscles of extremities relaxed.

"Four hours after these observations, the left hind leg was completely paralysed."

The lamb was evidently sinking rapidly, and could not recover. Accordingly it was killed, and the *post-mortem* appearances were as follows:—

"Several of the ecchymoses in subcutaneous tissue of lumbar region (probably because it had been lying for several days). Lungs comparatively healthy. Some strongyles. Liver showed at one part several grey-coloured nodules the size of a split-pea (perhaps small incipient abcesses). Kidneys, spleen, and other organs healthy. Small intestine showed several small punctiform ecchymoses in the serous coat. Solitary glands not enlarged. Rumen contained much undigested grass. Small intestine empty. Brain and spinal cord apparently quite healthy."

These are the symptoms and *post-mortem* appearances of what seemed an undoubted case of louping-ill. Mr. Scott, Drynoch, put his small laboratory at our service, and Mr. Hamilton and I remained for some days, in order to determine whether the disease was one of an organismal kind. We found in the blood, but especially in the cerebro-spinal fluid, a number of exceedingly small rounded organisms frequently going in pairs. We endeavoured to cultivate these in a weak decoction of mutton. The cerebro-spinal fluid was cultivated in drops of the decoction attached to the lower surface of thin cover glasses, which were set on rings of putty that had been arranged on glass slides, so as to form an efficient live-box,

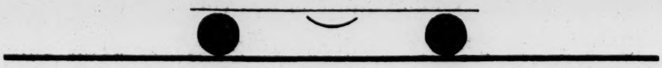


Fig. 1.

as in fig. 1. Three of these, along with other three containing drops of the decoction which had not been inoculated, were put in a

warm chamber for thirteen hours, when it was found that the three which had been touched with cerebro-spinal fluid were cultivating vigorously, while the other three remained barren.

The cultures consisted of little round organisms, which moved about rapidly either singly or in pairs, and were in some places aggregated so as to form a zooglæa, and across the field was stretched a fine branching mycelium.

A second culture was made from one of the slides, and after a few hours it was seen to be growing rapidly, but unfortunately a sudden rise of temperature succeeded the cold weather, for which the baths had been regulated, and all the cultures were exposed for some hours to a temperature over 100° Fahr., which put a stop to all growth.

The blood was cultivated in the same decoction, contained in test tubes plugged with cotton wadding, through which it had been previously boiled. The cultures grew slowly, but the appearances they presented were similar to those obtained with the cerebro-spinal fluid, though not so well marked. One of these which had been put aside for examination escaped the accident above referred to, and the cultures exhibited under the microscopes were derived from that source (fig. 2).

The results we have obtained so far lend strong support to the view that louping-ill is a disease due to, or connected with, an organism whose locus is chiefly in the cerebro-spinal fluid, but which also seems to be found in the blood. Arrangements have been made by Professor Williams, Mr. Hamilton, and myself to pursue this and other lines of inquiry in the season which is now at hand.

Braxy or "Sickness."

This is a disease which has been long known. It prevails over wide districts, and is very fatal. It usually runs a rapid course, and sheep attacked by it are generally found dead before they have been noticed to be ailing. The symptoms are very different from those of louping-ill. The patients display symptoms of great suffering; they are scarcely able to walk, but they stand with their head bent down and their feet drawn together beneath them. The abdomen becomes much swollen, and they lie down, and do not rise again.

After death putrefaction sets in very rapidly, attended with a peculiarly disagreeable and almost intolerable odour.

Post-mortem examination shows all the organs to be normal except the alimentary tract, which contains patches (sometimes very large) of intensely congested mucous tissue. These occur chiefly at the pyloric end of the fourth stomach and along the duodenum, but smaller patches are usually found far along the small intestine. The inflammation is confined to the mucous coat, the serous coat over the patches remaining quite healthy. The swelling is chiefly due to flatus, but the cases we examined also contained a great excess of peritoneal fluid, though no evidence could be found of peritonitis in the form of lymph over the surface or adhesion of the intestines.

A section of the congested mucous coat seen through the microscope presents a most extraordinary appearance. The tissue is densely crowded with large rod-like bacilli, and these especially crowd the interfibrillar spaces of the mucous and sub-mucous coats. The bacilli resemble the *Bacillus anthracis*, and they are found abundantly in the blood (fig. 3).

During the winter we cultivated the bacillus in various media, and find that it cultivates with great facility, even at ordinary temperatures. Under the microscopes on the table are to be seen preservations of the bacillus in its various stages of cultivation. The largest are those obtained by growing the organism in the peritoneal fluid itself; next are those obtained in serum and aqueous humour, and by cultivating from these in thin meat soup the bacillus becomes gradually smaller and more attenuated.

We hope that we may find that the attenuated bacillus may be found capable of being used for inoculating sheep, so as to insure them against death from this disease, in the same manner as has been practised in France with such brilliant success by Pasteur.

Professor Tait's papers on "Beknottedness," on "The Form of the Meridian Sections of Saturn's Ring," and on "The Velocity-Potential," were laid on the table. They will be printed at the end of the volume.

PRIVATE BUSINESS.

Mr J. A. Dixon, Professor D. H. Marshall, Professor C. Michie Smith, and Mr Josiah Livingston, were balloted for and declared duly elected Fellows of the Society.

Monday, 17th April 1882.

The Rev. W. LINDSAY ALEXANDER, D.D.,
Vice-President, in the Chair.

The following Communications were read:—

1. On the Definite Article in Greek, with special reference to the Revised Version of the New Testament. By Professor Blackie.

2. On the Action of the Microphone. By Professor James Blyth, M.A.

In the microphone transmitter, as usually employed in circuit with a battery and a Bell telephone, we have essentially two pieces of carbon resting lightly against each other, through which the current passes. That the instrument may work effectively two things are requisite,—first, that the carbons be always in contact, or at least sufficiently near for the current to pass between them; and, secondly, that they be not pressed together so tightly as to prevent any motion of the one relatively to the other. This state of things is sufficiently well described by the term "loose contact," first used, I believe, by Professor Stokes.

To understand the action of the microphone, we have to find out what effects are taking place at the loose contact when the instrument is acted upon by sonorous waves. These are twofold,—first, the effect produced by the sound waves (that is, the variation of density due to the condensations and rarefactions of the air) which pass directly through the air when they arrive at the loose contact; and, secondly, the effect produced by tremors set up in the entire instrument, wooden supports and carbons together, by the sound waves which strike against it and are thereby stopped.

For distinction, we may call the first of these the *air effect*, and the second the *tremor effect*.

In my experiments I have endeavoured to arrange the instrument so as to isolate these effects, and, as far as possible, examine each of them separately.

To isolate the air-effect, it is obviously necessary, either to fix the carbons rigidly in their supports, so as to avoid any motion of the one relatively to the other, or to use a strong current, and place them just clear of contact with each other.

The following experiment illustrates how this may be done :—

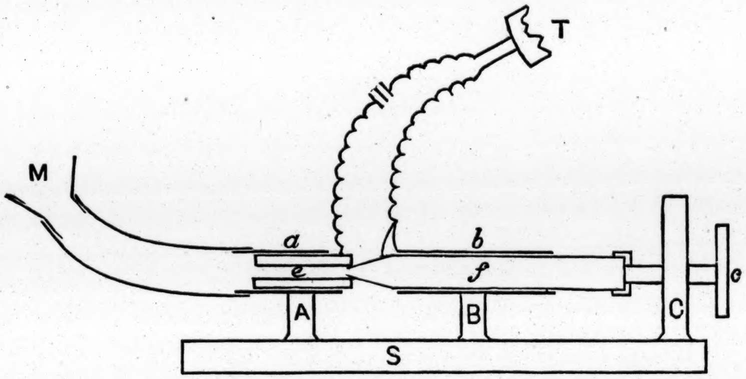


Fig. 1.

A, B and C (fig. 1) are three blocks of brass firmly fixed to a heavy wooden sole-plate S. To the top of A is soldered a piece of brass rod *a* about 2 inches long and $\frac{5}{8}$ inch bore. To the top of B is soldered a piece of similar tube *b* about 4 inches long. Through C passes a fine screw worked by a milled head *c*. A piece of carbon rod *e* is fixed firmly into *a*, and has a hole $\frac{1}{4}$ inch wide drilled through its centre. A long piece of carbon *f* pointed at one end, passes tightly through the tube *b*, and can be moved backwards and forwards by the screw *c*. A piece of india-rubber tube is passed over the left end of the tube *a* and carries the mouth-piece M. By means of the wires *g* and *h*, soldered to the carbon rods, they are put in circuit with the battery (20 Groves cells), and the telephone T, which must either have a small resistance or be placed in a separate circuit from that containing the battery, so as to be acted upon inductively. When the carbon *f* is screwed tightly into the hole *e*, the circuit is completely closed, and no sound uttered into M is heard at T. But when *f* is drawn gradually back, until small electric arcs are seen to pass between *f* and *e*, every sound uttered into M is distinctly reproduced in the telephone T.

Here we have clearly only the air-effect acting, and that solely upon the small electric arcs passing between the carbons. I have found it, as yet, somewhat difficult to get the sounds to last for any length of time, in consequence of the arc distance soon getting too great for the current to pass and requiring re-adjustment. When the arc begins and ends a sharp click is heard in the telephone; but in the interval during which the arc lasts the sounds heard in the telephone are distinct.

As far as the tremor effect alone is concerned, it is obvious that the microphone action must depend, either (1) upon the variation of resistance due to variation of pressure, or (2) to variation in the extent of surface contact due to the elastic yielding of the carbons under pressure.

To test the first of these causes, I made, about two years ago, some experiments on the effect of pressure upon the specific resistance of carbon. For this purpose, I took a short length of carbon rod, and soldered wires to it at a short distance from each end. By means of these wires, the resistance of the carbon rod was balanced in the Wheatstone bridge. Pressure was then applied by means of a lever to the carbon in a longitudinal direction. No appreciable variation in the resistance was observed, even under considerable pressure, and it only became manifest when the pressure was sufficient to bend or crush the carbon.

I have recently repeated these experiments with the greatest care, and found the same results. I observe, also, that similar experiments, with the same result, have quite lately been made by Professor Sylvanus Thomson. Hence we can hardly, I think, believe that variation of specific resistance due to pressure can have the slightest effect in producing the microphone action. To test the second cause above mentioned, that is, the variation of resistance due to variation, in the extent of surface contact due to elastic yielding under pressure, I experimented as follows:—

In the apparatus already described I replaced the tubular carbon by a finely pointed piece, so as to have two fine carbon points exactly opposite each other. The resistance of the points was balanced in the bridge in the usual way. Pressure was then applied by a known number of turns, or parts of a turn, of the fine screw, and the change of resistance noted. The screw was then brought back to its former position and the pressure relieved, so as to allow the elasticity of the carbon to act, and restore the points to their first condition. It is obvious that if the change of resistance were due merely to elastic yielding, it should now be the same as before. This I found not to be the case. From the gritty nature of the carbon, the points of contact I found were perpetually changing, and hence the variation of resistance produced in this way obeyed no regular law.

From this irregularity it is impossible, I think, to conclude that this cause could explain the transmission of musical sounds, far less articulate speech.

As far as my experiments go, the following appears to be something like the true explanation of the microphone action :—What I have termed the air and the tremor effects take place simultaneously. The tremor effect produces a jolting of the carbons, sufficient to allow momentary minute elastic arcs to take place between the points, which are just clear of contact with each other. Simultaneously with this the air effect comes in, and on account of the variations of density due to the condensation and rarefaction of the air, acts upon the minute electric arcs so as to vary their resistance. The tremor effect explains merely the production of the musical pitch of the sounds heard in the telephone, whereas it is to the air effect that we must look for the transmission of the quality of the sounds uttered into the microphone transmitter.

The microphone is thus so far a delicate make and break analogous to the old Reiss' transmitter, with the important addition, however, of minute momentary gaps filled with a material which is sensitive to the harmonic variations of the atmospheric density which constitute sonorous vibrations.

3. Experiments to Determine the Lowering of the Maximum Density Point of Water by Pressure. By Professor D. H. Marshall, Professor C. Michie Smith, and R. T. Omond, Esq.

(*Preliminary Notice.*)

These experiments were begun in January last at the request of Professor Tait, and have been carried on since then in his laboratory. The subject suggested itself to Professor Tait during his experiments on the effects of great pressures on thermometers carried out for the "Challenger" Expedition Commission, and it was indeed by part of the apparatus purchased by him for this purpose that the experiments were made. The method adopted was of an indirect nature, and consisted in determining first the change of temperature produced by a sudden change of pressure to which the water was subjected. Sir William Thomson has shown that if there be a sudden change of hydrostatic pressure on a body whose temperature is t and pressure p, there will be a change of temperature depending upon the change of pressure, the temperature t, the co-efficient of expansion at pressure p and temperature t, and the specific heat of the body at that pressure and temperature. In the case we are going to consider let t be the absolute temperature of the water, p its pressure, e its co-efficient of dilatation at pressure p and temperature t, and k its specific heat at constant pressure for the same pressure and temperature; let now there be a sudden change of pressure from p to $p - \delta p$, in consequence of which there is a change of temperature from t to $t - \delta t$,

$$\text{then } \delta t \propto \frac{te}{k} \delta p .$$

This formula can be absolutely true only for small changes of pressure. When water is subjected to great changes of pressure, k is possibly a little altered, and we shall show from our experiments that e is certainly so.

Since t and k are always +, on the assumption that k will change only very little by pressure, the sign of δt will depend upon that of e. Thus if e be + (as in the case of water above 4° C.), then for a sudden decrease of pressure there will be a decrease of temperature;

if e be – (as in the case of water under the ordinary atmospheric pressure between 0° and 4°), for a sudden decrease of pressure there will be an increase of temperature; and lastly, if a body have a maximum density point (as water under the ordinary atmospheric pressure) or a minimum density point, then just at that temperature there is no change of temperature for a small sudden change of pressure. If, however, when water at 4° C. is under great pressure, we prove that for a sudden change of pressure e is +, we at once infer that under such pressure water has not a maximum density at that temperature. It is in this way we have proved the lowering of the maximum density point of water by pressure, and also been able to approximate to the maximum density points under a few pressures.

The apparatus we used consisted of four parts: (1) the apparatus for producing the compression, consisting of a strong iron vessel (called the small gun) and a powerful force pump; (2) the gauge; (3) the galvanometer, to measure the changes of temperature following changes of pressure; and (4) an extra thermo-electric circuit, to determine the values in thermometric degrees of the galvanometer deflections.

The first two pieces of apparatus have already been described by Professor Tait in the account of his experiments above alluded to.

The changes of temperature which followed changes of pressure were measured by thermo-electricity. One junction of a thermo-electric circuit of very fine copper and iron wire was placed inside the gun, the wires passing out between two discs of leather well soaked in oil near the bottom, which could be taken off. The others were soldered to thick copper wires in connection with a dead-beat reflecting galvanometer, and placed in a vessel of water, which was kept at as uniform a temperature as possible, one of them being put into a test-tube to prevent the slight voltaic action which disturbed us in our earliest experiments. As we had in some of our experiments to measure extremely small changes of temperature, the galvanometer was made very sensitive by the controlling magnets, and the deflections read on a scale about $2\frac{1}{2}$ metres from the galvanometer. We were enabled in this way to measure as small a change of temperature as $\frac{1}{500}$° C. even with a single thermo-electric pair. However, any change in the electric field was at once felt. The rooms we worked in were on the ground flat looking into Chambers Street, and every passing vehicle, on account of its iron fittings, disturbed us. The reader of the galvanometer scale, who was in a darkened room by himself, could generally tell the direction in which a vehicle was moving from the motion of the image on the scale, and on once crying out that a man walking past affected the galvanometer, the experimenter at the pump immediately rejoined that he was carrying some iron on his back. To avoid this change of the magnetic field, we took one set of observations at midnight.

As it was generally impossible to determine directly with a thermometer the temperature of the junction inside the gun, to enable us to interpret the galvanometer readings there was an extra thermoelectric circuit, as nearly as possible the same as that connected with the gun, whose junctions were in vessels of water, so that the temperatures could be directly read with a thermometer and altered at pleasure. Any change in the sensitiveness of the galvanometer was each day detected by this arrangement. During the principal experiments we found it necessary to have three observers, as it was necessary to read the gauge, thermometer, and galvanometer, and let off pressure simultaneously. We think it sufficient in the meantime to indicate briefly the results of a few of the principal experiments made. For example, when the internal junction was at a temperature of 8°·3, for a sudden decrease of pressure from 300 atmospheres to 1, there resulted a decrease of temperature = 0°·17. As the pressure increased, so did the rate of cooling with pressure; and at a temperature of 9°·3 for a sudden change of pressure from 750 atmospheres to 1, there was a cooling = 0·°74. We next operated with the internal junction at a temperature less than 4° C. At a temperature of about 1°·3 for pressures less than 180 atmospheres there was heating instead of cooling for sudden decrease of pressure, which meant that e was $-$; at the above pressure and temperature e apparently vanished, which meant that at a pressure of 180 atmospheres the maximum density point was about 1°·3; at greater pressures e was $+$, which meant that the maximum density point was still further lowered.

The experiments we made at midnight corroborate these results.

There are several points to be carefully considered, such as the most satisfactory way of protecting the internal junction from currents produced by change of pressure, convection currents arising from the lowering of the maximum density point, and the possible change of specific heat, which prevent us yet from giving quantitative results. So far as we have gone, our results agree fairly with those of Professor Tait (*ante*, p. 204).

Monday, 1st May 1882.

Mr MILNE HOME, Vice-President, in the Chair.

The following Communications were read :—

1. On some Points in the Meteorology of Madeira, both Absolute and Comparative. By the Astronomer-Royal for Scotland.

2. On the Anatomy and Histology of *Pleurochæta Moseleyi*.

By F. E. Beddard, B.A., New College, Oxford.

(*Abstract.*)

This earthworm, which is an inhabitant of Ceylon, is 28 inches in length, and consists of about 260 segments. The setæ, instead of being arranged in continuous lines round the body as in *Perichæta*, fail for a short space both dorsally and ventrally. This peculiarity serves to distinguish the genus *Pleurochæta* from other *Oligochæta*. The intestine is provided with two sets of specialised glands; the anterior, occupying from segments twenty-two to forty-four, consists of a double series of deeply excavated dorsal pouches on the wall of the intestine, provided with a large development of glandular epithelium; the posterior glands are solid and kidney-shaped, about the size of a grain of wheat. They lie on the dorsal surface of intestine, occupying from the eighty-fifth to the one hundred and first segments; in all, fifteen pairs. They open into intestine by ducts.

The generative system consists externally of a clitellum, occupying in one of the two specimens that I examined as many as nine segments. On this open the generative apertures, three pairs of which are situated close together in a sucker-like structure at the posterior end of the clitellum, upon which there is no development of glands; each pair corresponds to one of the three segments, seventeen, eighteen, and nineteen. The middle pair open into two large "prostates"; no ducts were found in connection with the other two pairs. There is also a fourth pair of apertures on fourteenth segment, with which again no ducts were discovered to be continuous. The testes are a pair of racemose glands occupying twelfth segment. Two pairs of fimbriated organs, occupying eleventh and tenth segments, are perhaps the oviducts, or possibly the vasa deferentia. They open separately on the wall of the segment behind that in which they are situated.

There are no segmental organs present. The vascular system presents no important differences from that of other worms. The dorsal and ventral vessels are connected by six pairs of hearts increasing in size from before backwards, and occupying from the eighth to the thirteenth segments inclusive. There appear to be no intestinal hearts ("cœurs intestinaux" of Perrier), though the supra-intestinal vessel is present, and in that region of the body in which the hearts are developed is double. Capillaries extend into the hypoderm as in the leech, the fibres of the two muscular coats of the body wall as separated into smaller and larger bundles by a meshwork of fibrous connective tissue. The perivisceral cavity is put into communication with the exterior by a series of dorsal pores.

3. Geological Notes. By Dr. Heddle.

Leaf-bed in Canna.

Since the discovery, by His Grace the Duke of Argyll, of the "Leaf-bed" at Ardtun, in Mull, there has not, so far as I am aware, been another found throughout the whole of that extent of land and shore, where we might hope for such a discovery, among the Inner Hebrides.

It was my good fortune to light upon one last summer. While lying in the harbour of the island of Canna, during a boulder and mineral hunt, I heard that *fuller's earth* had been found at the south-western end of the island. Upon being shown samples of this, I noticed among them fissile schists very similar to those of Ardtun. In proceeding, therefore, round the western cliff-girt coast of the island, to visit the fuller's earth locality, we landed at every accessible point under the great line of precipice, and at one, situated almost at the north-west corner, and immediately under the loftiest point,—more than 730 feet in height,—we found a leaf-bed. There is here a cliff foot, running for some little distance along the shore; this is strewed with numberless masses of rock which have fallen from the cliff, and which fragments give shelter to a colony of auks and puffins.

By the appearances usual to such colonies, the spot may be seen from some distance. Landing can be effected only in the calmest weather.

The leaf-bed can be most easily cut into, if not also most easily seen, in a small cave; this gives shelter alike from what may fall from the cliff, from the skies, and from the birds.

The bed consists of a highly laminated brown clay—almost a mud; for, on account of the water which ooses through the very-vesicular overlying dolerite,—which streams down its face, and which is flung in spray from the sea,—the material of the bed is in its outer portions, and, when first broken into, little harder than putty. Its laminæ are as thin as paper. They split with a tap, or slight pressure from the edge of a knife; this easy cleavage being to some extent due to the extraordinary number of *leaves* which lie, flat-pressed, between the argillaceous layers. Most of these leaves are as pulpy and soft as the rock, and blacken the hands with their fragile fragments.

By working with a pick-hammer a little way under the rock-cover, firmer portions may be reached; and specimens which will endure the friction of carriage obtained. The leaves seem much the same as the species found at Ardtun. A series has been sent to the Industrial Museum.

The whole thickness of the towering cliff is made up of successive layers of igneous rock,—sometimes basalt and basaltic—sometimes amygdaloidal,—sometimes tufaceous. I could distinctly see bands of *plynthite*, which may here represent an overflowed and burnt layer of clay-soil. I also imagined that I could with a binocular make out other beds of the same fissile clay as that which, at the cliff foot, holds the plants.

As there was a gentle dip towards the south-west, I was prepared to find that one or other of these beds had come down to the water edge; to form, when puddled by the waves, the so-called fuller's earth;—and this was very much the true state of matters. A washed-out dyke, conjoined with a small fault, has formed a "geo," terminating in a cave. At flood-mark the waters stand in part of this cave. Surface waters are also constantly sapping into it from above; making it more ample, by reducing to pulp, and carrying away the exposed edge of a bed of much the same rock as that which has been already noted as carrying the leaves. The fuller's earth was found to be, at the time of our visit, of about the same consistence as pea-soup. By taking portions of the dry bed, pounding them, floating off in water, and sedimenting, I *made* some,—decidedly superior to the native article. A sample of this I sent to the Museum.

The Pitchstone-Porphyry River of the Scuir of Eigg.

The pitchstone plug of the river-cañon of Eigg, forming the singular Scuir,—picturesque from certain points of view, weird and fantastic from others,—should be about equally well known to scenery hunters and to geologists. The filled-up water trench is not of great length; somewhere about two miles, as its historian tells us. This is but a short junk of such a mighty river as that must have been, which cut a channel at least 400 feet deep and about 1000 wide. As the eye ranges over a wide expanse of ocean at the spot where this pitchstone cast is shorn off at the *west*,—and as no remaining fragment of the widespread lands from which its waters must have been gathered on the *east*, now remains,—there seemed to be but little hope of our collecting any further fragments of its history. Chance threw the writer upon one such fragment. I was looking for boulders everywhere; Mr. Harvie Brown was looking after grey seals, and birds' eggs, grey, green, or blue; and so we landed upon Hyskier. *Hyskier*—that is, the High Skerry; only 40 feet, but high enough to afford some sort of a shelter to boats which might fly for safety to the little rock-girt lagoon, which is cinctured by its clustering rocks.

There are two Hyskiers,—one outside Long Island, the other inside. Both are famous for their seals, and both are "rude" enough, if that word was used by Sir Walter to express roughness. It is the *inner* Hyskier that is the subject of these remarks. It is about 9 miles from the nearest land of Canna, with a deep-water channel all round. It consists of a group of skerries, almost united at low water.

Upon landing, myriads of boulders of every variety of rock were seen; and the writer at once recognised the pitchstone porphyry of the Scuir of Eigg, as the rock upon which the boulders lay. The whole clustre of skerries is formed of the same rock; which, both in the dun grey of its tone of colour, in the proportional quantity of crystals of imbedded sanidine—and in the size of its basaltic pillars, is unmistakably the same rock as that of the Scuir. This is a markedly characteristic one;—one which, in fact, is distinct from all other pitchstones of Scotland.

Standing on these skerries, the eye looks directly on the truncated end of the Scuir, which is about 22 miles distant. It ranges also somewhat along its southern flank, as the course of the ancient river of Eigg had been a tortuous one. But its last convolution on that island was a flexure *somewhat more southerly* in its direction than its general course. This direction threw it clear of the south of Rum, and pointed very much to the solitary cluster of pitchstone islets of Hyskier.

The most southerly skerry of the cluster is separated from that nearest to it by a deep wall-sided channel. This, to appearance, was about 4 or 5 fathoms in depth; and the mural cliffs in each side rose to a height of about 23 feet. (It was low water at the time.) The channel was perfectly straight in its course. At first sight it resembles a washed-out dyke. With the knowledge we have, however, of the nature of the Scuir, it very much more probably represents what had been a wall-sided islet, which stood midstream in the ancient river; its amygdaloids and tuffs having now been sapped out by the surf, as have the old river banks and the surrounding land.

On a supposed Organism from the Marble of Sutherland.

I have never seen fit to express an opinion upon the vexed question of the *eozoon canadense.* This, not because I have *not* formed an opinion, but because I have never seen specimens sufficiently characteristic to furnish me with grounds ample enough to enable me to *give force* to my opinion; also because I consider that certain of the grounds adduced by those who hold the same view as my own, are weak, or at least not strong, from a mineralogical point of view.

Having myself found, and being as yet the only one who has studied *the mode of occurrence* of the structure to which I now direct attention, it may be considered that a similar amount of reticence is not in its case either reasonable or justifiable.

The thing of which I write was found in the white saccharine marble of Sutherland last summer. I have during many summers made myself familiar with the modes of occurrence of minerals,—in fact, I have become a successful *mineral hunter*, just in virtue of familiarity with the *modes of occurrence* of minerals; I am perhaps then not going too far in saying that when, after a full consideration of the mode of occurrence and structure of *that thing*, I concluded that it does not accord with minerals, *either in mode of occurrence*, or *in structure*, it must be at least worthy of the attention of those who are more familiar with structures *not mineral* than I am.

As *the thing* at first sight looked exceedingly like eozoon (what I knew of it), and as its resemblance to eozoon only increased the longer I looked at its sections (which I prepared with my own hands, in all directions), I sent it to Dr. Carpenter, making over to him *in toto* the investigation of its *inner nature*, but reserving to myself—that which he could not do—the telling all the rest about it.

I was well aware that, in concluding that it was wonderfully like, if not identical with, eozoon, I was giving to it a stratigraphical position which many would hold was one "where nae sic thing should be;" but, as it is one of the tenets of my geologic faith, that where a thing *is*, is where that thing should be, I was not much disturbed in my conclusions.

I am permitted to say, and it may be well that I should state this much, that Dr. Carpenter reports that its appearance is very eozooic, while later letters say "exceedingly interesting."

Such are the essentials of its interest which induce me to lay before the Society these notes upon a substance of whose description it is evident that my share must lie only on the mineralogical side.

While endeavouring to discover the bedding of the almost amorphous white marble, my eye was arrested by a dark streak, which promised some aid. Upon approaching it, it presented an appearance similar to what we have been assiduously taught to believe would be presented by a junk of the great sea-serpent. It also somewhat resembled the old "*boas*" worn by ladies, laid horizontally on a face of the marble; and it was *altogether similar* in appearance to the whale cutlets which are hung or stretched in the sun to dry, in the Faröe Islands.

The first portion found lay imbedded in the marble, about 2 feet from its surface. Its length was 16½ feet, and its thickness 4 to 5 inches. When found, I was carrying only a four-pound hammer; but, upon Dr. Carpenter reporting "high interest," I returned to Sutherland with one of more earnest dimensions; and by removing the cover, found that in parts it extended, with almost unvarying thickness, into the rock for 3½ feet.

It lay in the rock in slightly wavy folds; at one spot it threw off, at an angle of about 15°, an arm or *process*; this was about an inch narrower than its mean trunk, and of about 2 feet in length; at another spot it threw off a short process, at right angles.

Its exposed surface was much corroded by the weather, but its structure was unfolded thereby. That boldly displayed structure consisted of gently-plicated but very rough layers of a substance, which evidently was less soluble in rain-water than had been that whose removal left the layers protruding.

The appearance of this exposed surface is precisely that of the representation of eozoon given by Carpenter, in the last edition of his work on the Microscope; and the colour is very much that of printer's ink. When broken into, the rippled structure stands out in blue-black, upon a nearly white ground, which is mottled with granules of yellowish-grey. Occasional patches of greenish-yellow granular precious-serpentine occur; there occasionally are nodules of the latter the size of the fist, and this sometimes is white.

That mineral speaks for itself. As to the others, I found the blue-black in distant octahedral crystals: they are *spinel*, possibly *picotite*, though I have not determined the presence of chromium. The grey-yellow granules are generally rounded on the angles, as is so frequently the case with minerals imbedded in a limestone which has been subjected to the extreme energy of metamorphism. But this substance I have also got in crystals. These are of a pale fawn colour, identical with that of danburite; but the form of the crystal is that of *chondrodite*. The presence of fluorine I have not yet determined; and as there is a form of *sahlite* almost indistinguishable from that of chondrodite, I will not say that these crystals may not be *this* mineral, which is the common ingredient of such marbles. The white matrix (soluble in the rain-water) afforded me, on analysis—

Carbonate of lime, . .	46·307
„ magnesia, . .	37·632
„ iron, . . .	1·022
„ manganese, . .	·368
Insoluble (chondrodite ?), .	15·108
	100·437

and is thus a ferruginous dolomite.

Such are the chemical and mineralogical materials of which this fabric is composed. The fashion and mode of arrangement of these materials I leave others to unfold; inasmuch as they appear to me not to have been subject to the laws which govern molecular arrangement in crystals; and that hence, the thing, as a whole, is not a mineral body, but an organism.

When it shall have been said, in leaving the question at this stage,—standing aside to give the histologists and palæontologists *their* innings at the describing of *the thing*,—that I am merely evading a duty, self-imposed in virtue of the foregoing expression of opinion, I shall be prepared to state the grounds upon which I hold that its structure cannot fall to be considered under crystallipolar arrangement. Meanwhile, I think it well to leave that which is to be seen to those who can describe the complexities of flowing lines and curvilinear outlines, so much better than one who deals with straight lines and angular inclinations.

4. Note on the Absorption of Sea-Water.

By Mr. John Aitken.

In a letter to Professor Tait, dated Mentone, 14th April 1882, Mr. Aitken says :—

Since coming here this time, I have tested the sea with the polariscope and with the spectroscope. With an instrument by Hoffman, which gives coloured bands with polarized light, I have been able to detect small, but decided indications of polarization in the light internally reflected by the water, the surface reflection being, of course, cut off when the observation was made. At present I think the polarization is due to regular reflection from the polished surfaces of some of the particles, which are seen to glance brightly in concentrated sunlight.

I have also detected an absorption band in the green of the spectrum of the light internally reflected by the Mediterranean water. This band is much more distinct in water where there are but few reflecting particles, and the light undergoes a great amount of selective absorption. At about a mile from shore, where I could see a white surface 6 inches square at a depth of 16 metres, the absorption band was quite distinct, but became less and less as I approached the shore, where there was more matter in suspension and the water less transparent, but the spectrum more brilliant. I cannot say whether this band belongs to water or to salt, or to what it is due, never having noticed it before; but I never examined water so transparent, and where the light had undergone so much absorption.

PRIVATE BUSINESS.

Dr. David Pryde, Mr. J. W. Inglis, Mr. F. W. Young, and Mr. T. R. Buchanan, M.P., were balloted for, and declared duly elected Fellows of the Society.

Monday, 15th May 1882.

PROFESSOR BALFOUR, Vice-President, in the Chair.

The following Communications were read:—

1. Exploration of the Faroe Channel, during the Summer of 1880, in H.M.'s hired ship "Knight Errant."* By Staff-Commander Tizard, R.N., and John Murray; with Subsidiary Reports on the—

Echinoidea	by	Professor Alex. Agassiz.
Foraminifera	,,	Mr. H. B. Brady.
Copepoda	,,	Dr. George S. Brady.
Polyzoa	,,	Dr. Geo. Busk.
Fishes	,,	Dr. A. Günther.
Radiolaria	,,	Professor Ernst Haeckel.
Pycnogonida	,,	Dr. P. P. C. Hoek.
Mollusca	,,	Mr. Gwyn Jeffreys.
Ophiuroidea	,,	Professor Theodore Lyman.
Annelida	,,	Dr. W. C. M'Intosh.
Crustacea	,,	Rev. A. M. Norman.
Diatomaceæ	,,	Dr. James Rae, R.N.
Deposits	,,	Mr. John Murray. Professor A. Renard.
Asteroidea	,,	Mr. W. Percy Sladen.
Holothurioidea	,,	Dr. Hjalmar Théel.
Sponges	,,	Professor F. E. Schulze.
Sea-water	,,	Professor W. Dittmar.
Rocks of N. Rona	,,	Mr. John Murray. Professor A. Renard.

Communicated by Mr. Murray. (Plate VI.)

I. INTRODUCTION.

The region known as the Faroe Channel is that portion of the Atlantic Ocean to the north of the mainland of Scotland, which is bounded on the N.W. by the Faroe Islands, with their south-west-

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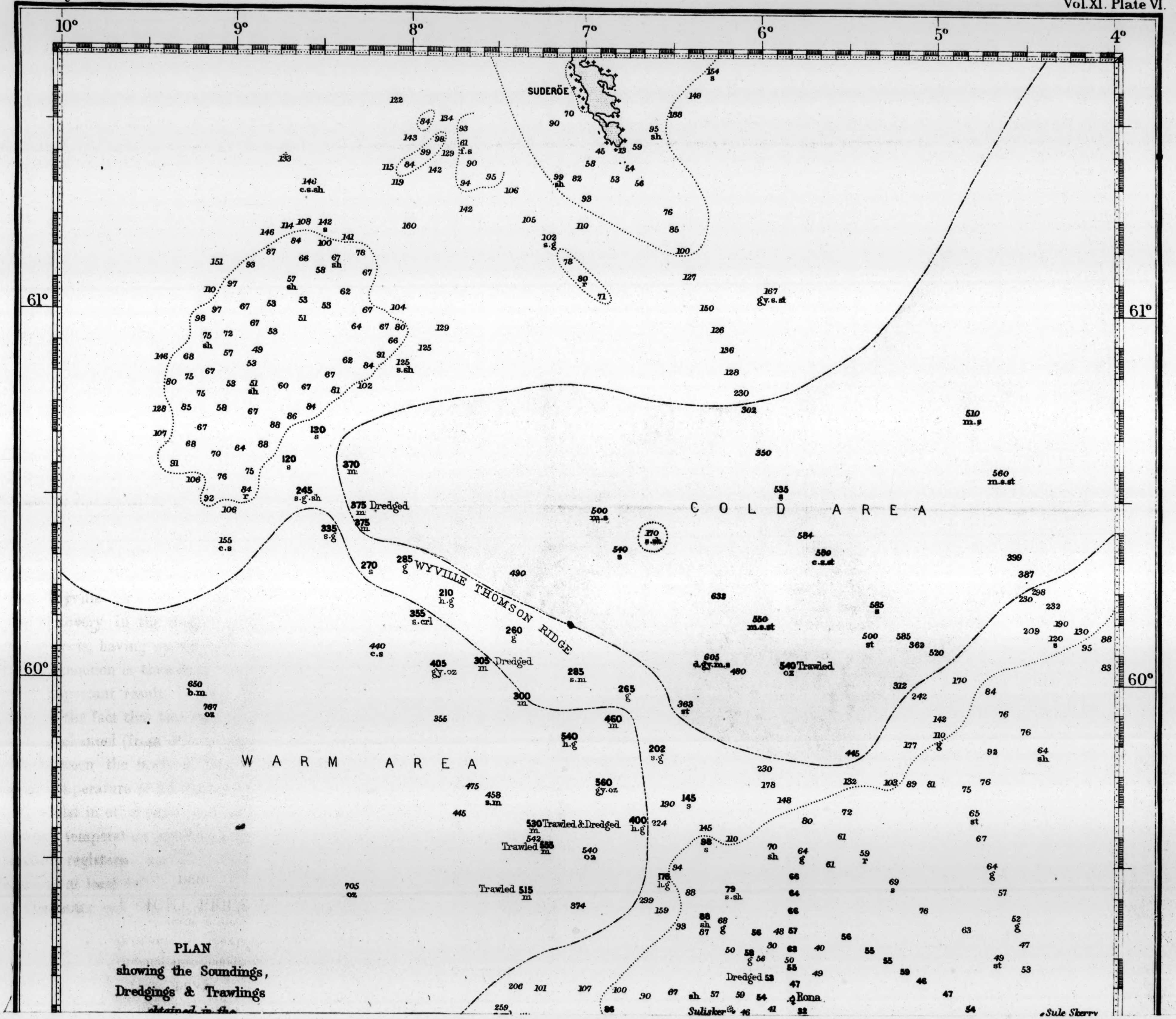
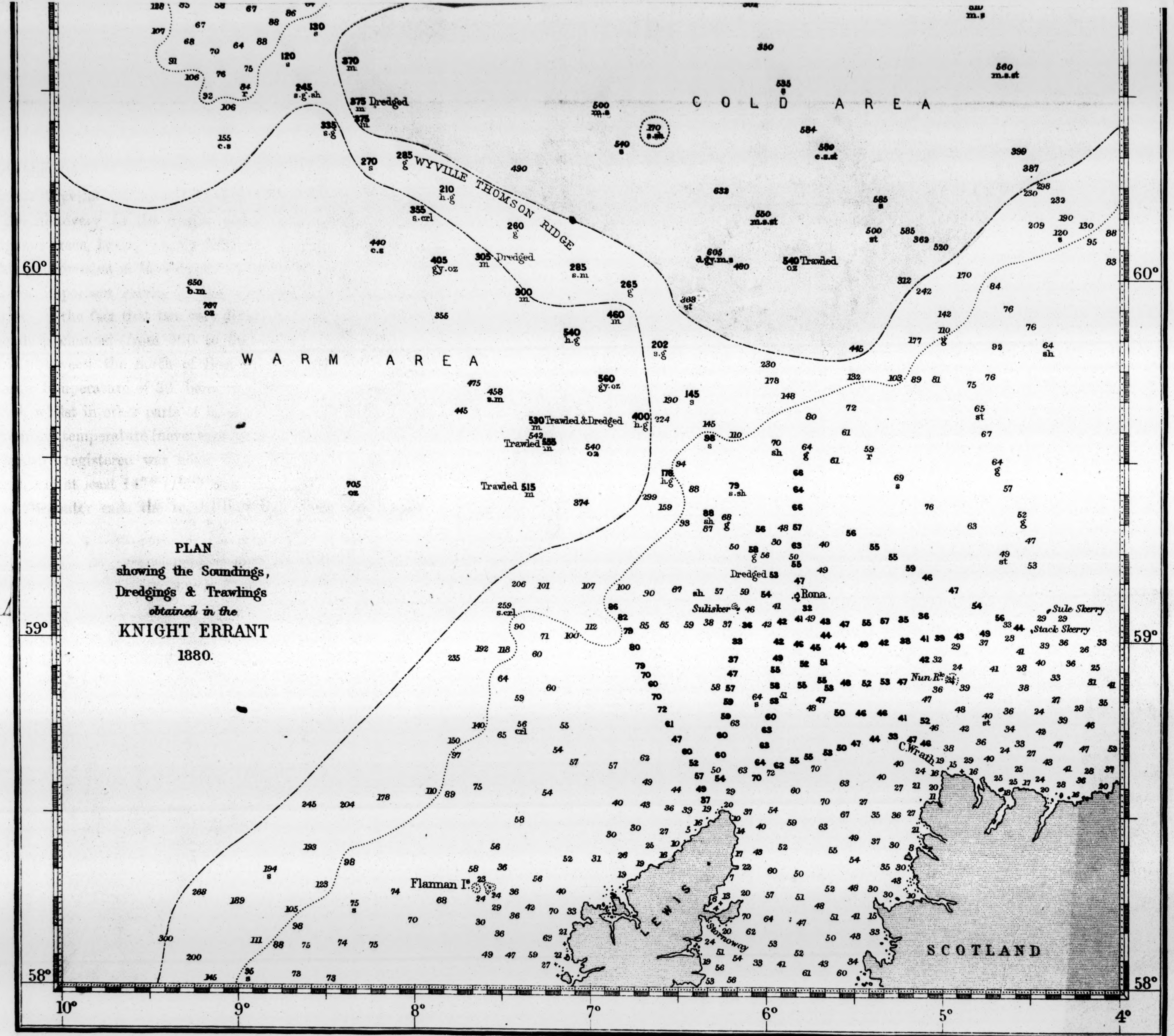
* A short preliminary note on the cruise of the "Knight Errant," by the late Sir C. Wyville Thomson, will be found in *Nature* for September 1880.

Most of the materials for the present communication were prepared in December 1880, and handed to the late Sir Wyville Thomson. It was Sir Wyville's intention to describe the Echinoderms, write a general introduction, and arrange the whole for publication. The feeble state of his health, and the pressure of other work, prevented this intention from being carried out.


10°
9°
8°
7°
6°
5°
4°
61°
60°
SUDERÖE
COLD AREA
WARM AREA
WYVILLE THOMSON RIDGE
375 Dredged
305 Dredged
540 Trawled
530 Trawled & Dredged
Trawled 555
Trawled 515
Dredged 53
Rona
Sulisker
Sule Skerry
PLAN
showing the Soundings,
Dredgings & Trawlings
obtained in the



PLAN
showing the Soundings,
Dredgings & Trawlings
obtained in the
KNIGHT ERRANT
1880.

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ward extending fishing-banks, and on the S.E. and S. by the Shetland and Orkney Islands, the shores of Caithness and Sutherland, and the Hebrides.

The Faroe Islands are composed of basaltic rocks, while the north of Scotland, and the Scottish Islands, are chiefly made up of Laurentian gneiss, Silurian, and Devonian rocks.

The average width of the Faroe Channel, throughout its more defined and restricted portion, that is to say, between the 100 fathom line of soundings off the coast of Scotland and the Scottish Islands, and that of the Faroe plateau, is between 80 and 90 miles, and the maximum depth rather more than 700 fathoms.

At the south-westerly end the depth increases gradually to the mean depth of the "Cable Plateau" of the North Atlantic, and towards its north-easterly extension it deepens gradually to the lowest bed of the Arctic Ocean.

Up to the time of the recent investigations the bottom was regarded as irregular, as the soundings seemed to indicate one or two dome-like elevations, rising towards the centre of the trough, to within 200 fathoms of the surface.

The Faroe Channel has acquired special interest, because, so far as England is concerned, it is the region where systematic deep-sea investigations were first carried on.

One of the most interesting results of the investigations of the "Lightning" and "Porcupine" expeditions under Dr. Carpenter, Professor Wyville Thomson, and Mr. Gwyn Jeffreys in 1868–69, was the discovery in the deeper water of the Faroe Channel of contiguous areas, having widely different temperature conditions.

This phenomenon is thus described by Dr. Carpenter:—"Among the most important results of the 'Lightning' expedition was the discovery of the fact that two very different submarine climates exist in the deep channel (from 500 to 600 fathoms) lying E.N.E. and W.S.W. between the north of Scotland and the Faroe banks; a minimum temperature of 32° being registered in some parts of this channel, whilst in other parts of it, at the same depths, and with the same surface temperature (never varying much from 52°) the minimum temperature registered was never lower than 46°, thus showing a difference of at least 14°" (*Proc. Roy. Soc.*, 1869, p. 453).

Dr. Carpenter calls the regions indicated above the "cold" and "warm" areas respectively, but during these early investigations, there seems to have been no suspicion that these two areas might be separated by a submarine barrier. Two bodies of water, differing from one another by 14° Fahr., were, at this early stage of deep-sea investigations, even regarded as abutting against one another without any intervening barrier. Professor Wyville Thomson says:—"In the Faroe Channel the warm water forms a surface layer, and the cold water underlies it, commencing at a depth of 200 fathoms,—567 fathoms above the level of the bottom of the warm water off the Butt of the Lews. The cold water abuts against the warm—there is no barrier between them. Part of the warm water flows over the cold indraught, and forms the upper layer in the Faroe Channel. What prevents the cold water from slipping, by virtue of its greater weight, under the warm water off the Butt of the Lews? It is quite evident that there must be some force at work keeping the warm water in that particular position, or, if it be moving, compelling it to follow that particular course" (*Depths of the Sea*, p. 395).

II. ORIGIN AND OBJECTS OF THE "KNIGHT ERRANT" INVESTIGATIONS.

How these early trips of the "Lightning" and "Porcupine" in 1868–69 led to the equipment of the "Challenger" for a circumnavigating cruise is now a matter of history. One or two general considerations with regard to the movements of ocean water, which were established by the "Challenger" observations, may be here referred to, as having led to a reinvestigation of the Faroe Channel.

The waters of the ocean are everywhere in a state of movement, —not a mere state of oscillation by the tides, not a surface movement by shifting winds,—but a steady massive movement, affecting the ocean throughout its whole extent and depth.

The deeper currents are in general so slow that it is impossible to detect their movement directly by the current drag, or any other instrument which has yet been constructed. By means of the thermometer, however, these deep currents can be traced to their source, and their depth and direction determined.

Conduction takes place in masses of water with such extreme slowness, that, when a large mass of water has acquired a given temperature, it may retain it for an almost indefinite period, and move over a vast area without losing much of its heat.

The massive movement of the waters of the ocean is, broadly speaking, from the equator to the poles on the surface, and from poles to equator at the bottom—the cause of this movement being difference of density arising from varying temperature and saltness, and the direction being due to the greater specific gravity of cold than warm salt water.*

The normal distribution of temperature in the great oceans, as found by the "Challenger" may briefly be described as follows:—Towards the surface the warmest water is found, the surface layers being greatly heated by solar radiation; the water cools rapidly downwards for the first 200 fathoms, slowly down to 500 or 600 fathoms, then very slowly to the bottom, where the minimum temperature is reached. This normal vertical distribution of temperature in the ocean is, however, by no means universal.

It is frequently found that the minimum temperature is reached at several hundred or thousand fathoms above the bottom, as, for instance, in the eastern basin of the Atlantic extending along the coasts of Europe and Africa, where the temperature sinks steadily to 36·5° Fahr. at a depth of 2000 fathoms, and then this temperature extends to the bottom at 3150 fathoms. One or two remarkable instances of this abnormal distribution of temperature may be mentioned.

In the Celebes Sea, which attains a depth of 2600 fathoms, the minimum temperature (38·6° Fahr.) is reached at 800 fathoms; the Banda Sea, with a depth of 2800 fathoms, reaches its minimum temperature of 38° Fahr. at 900 fathoms; and the Sulu Sea, which is at least 2550 fathoms deep, has a uniform temperature of 50·5° Fahr. from a depth of 400 fathoms to the bottom. World wide examples of the same phenomenon were found during the "Challenger" investigations. Two neighbouring stations frequently gave water at the same depth, at temperatures differing often by many degrees.

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* See papers by Prof. Tait (May 16, 1881, *Proc. Roy. Soc.* Edin., vol. xi. p. 217), and by Profs. Marshall and Smith and Mr. Omond (read before Roy. Soc. Edin., July 3, 1882), on the effect of pressure on the maximum density point of water.

Viewing these temperature observations with the indications given by the soundings, we arrived at the generalisation—that contiguous areas with widely different bottom temperatures were separated by submarine barriers, and that *the depth at which the minimum temperature was found in one of the areas, indicated the height of the barrier.*

The following diagram (fig. 1) will illustrate:—

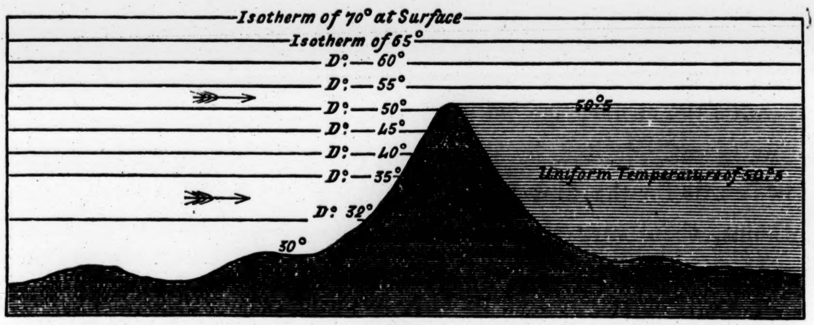

Fig. 1.

The water which is cooled down in the Polar seas, and has thus acquired a high specific gravity, flows along the bottom into the deepest part of the ocean to which it can find access, as shown by the arrows. The surface of the earth below, as well as above the level of the sea is irregular, and the result of this irregularity is that masses of water meet with barriers, over which they must pass, like that represented in the diagram (A).

A barrier like this surrounding a depression, cuts off the lower and colder layers of water, and the basin beyond is filled with water at a uniform temperature by an overflow, the temperature being the same as the water at the height of the ridge, as shown in the diagram.

In any region, then, where we have different bottom temperatures in contiguous areas, and where the minimum temperature in one of the areas is reached at some distance above the bottom, we thought we had reason to believe that the point at which the minimum temperature is found indicates the height of the submarine ridge which cuts off the underflow.

This generalisation induced Captain Tizard to predict the existence of a ridge rising to within 200 or 250 fathoms from the surface between the warm and cold areas of the Faroe Channel.

This opinion was founded upon the following considerations :—

1. If an imaginary line be drawn from North Rona to the southern end of the Faroe fishing bank, all the bottom temperatures obtained in the cold area were situated to the N.E. of this line, whilst those obtained in the warm area were to the S.W. of it.

2. The warm and cold areas had actually been traced across the channel on either side of this imaginary line with the exception of about thirty miles towards the Faroe fishing-banks.

3. That the serial temperatures in the two areas were nearly similar to the depth of 200 fathoms, but at greater depths showed a marked difference.

The whole direction of the "Challenger's" inquiries was new, and the methods and appliances were hitherto untried; nevertheless, a very fair general idea of many leading phenomena was acquired, and an intelligible basis was laid down for a novel section of the science of Physiography.

Our observations, however, extended over the widest areas, and were restricted to sketching in the merest outline—no single locality was exhaustively examined, no single phenomenon was thoroughly studied.

We had no opportunity of ascertaining by actual soundings the existence and continuity of any one of the ridges, the existence of which we inferred from our temperature observations.

The Faroe Channel afforded an accessible and limited area, with abnormal temperature conditions which might in a comparatively short time be examined in detail, with the probable result of a satisfactory solution of not a few questions of frequent occurrence, of great complexity and of very great interest for science.

These circumstances were set forth in a letter addressed to Sir Frederick Evans, K.C.B., hydrographer to the Admiralty, by the late Sir Wyville Thomson, dated June 16, 1880. (See *Nature*, 2nd Sept. 1880.)

Sir Frederick, whose great interest in deep-sea investigations is well known, had no difficulty, especially as soundings for the general purposes of navigation were required in this region, in recommending this matter to the favourable consideration of the Lords

Commissioners of the Admiralty, with the result that the "Knight Errant"—a hired surveying vessel employed on the west coast of Britain—was instructed to carry out this service.

The object of this cruise was (*a*) to ascertain by actual soundings (over the space between the positions, where warm and cold bottom temperatures had been obtained in the "Lightning" and "Porcupine") whether a submarine ridge existed, (*b*) to extend our researches to those portions of the Faroe Channel hitherto unexplored, and (*c*) to obtain a few serial temperature observations and trawlings in each area.

The plan we proposed to follow in searching for this ridge, was to run sectional lines of soundings at given intervals across the channel N.E. of the warm bottom temperatures previously obtained, and southward of those in the cold area.

In this way the bottom temperature would be ascertained at each depth, and we should then gradually narrow the locality to be sounded over in looking for the ridge itself.

If we obtained a sectional line in which the bottom temperatures were all warm, we should be, according to our theory, S.W. of the ridge, but if the bottom temperatures were cold, N.E. of it.

Thus we hoped to draw the sectional lines nearer and nearer, until, either we proved the existence of the ridge, or ascertained, what appeared to us to be most improbable, that a bank of cold water was in contact with water of a much higher temperature. Having ascertained whether the ridge existed or not we proposed to devote the rest of the time to taking some serial temperature observations, dredgings, and trawlings, both in the warm and cold areas.

III. NARRATIVE OF THE CRUISE.

The "Knight Errant" arrived at Stornoway on the 24th of July 1880, and left that port again for the south on the 20th of August. During this period she made four trips to the Faroe Channel.

The original intention was to confine our attention to sounding operations. We did not, however, like to allow the opportunity to pass of taking a few dredgings and trawlings—consequently Sir Wyville supplied the ship with dredging rope, trawls, and dredges at his own expense, and Messrs. D. & W. Henderson, Engineers, Glasgow, kindly placed one of their steam winches at Mr. Murray's disposal, and fitted it on board. Sir Wyville remained at Stornoway while some of the investigations were being carried on.

First Trip.

We left Stornoway on Monday the 26th of July, and proceeded out towards Rona Island. On Tuesday the 27th we commenced running a sectional line of soundings towards the S.W. of the Faroe Islands, and obtained on that day eight casts of the lead. The bottom temperatures were similar to those obtained by the "Porcupine" in the warm area.

At 8 P.M. the dredge was put over in 305 fathoms, the wind and sea were moderate, and the weather bright enough to allow the position of the ship to be fixed accurately by astronomical observations.

Several hauls of the tow-net were taken at intervals when sounding. Early on Wednesday the 28th July, the dredge was hauled in and found to contain stones, sponges, polyzoa, &c.

The sectional soundings were resumed, and six casts were obtained before striking the edge of the Faroe fishing-bank, the temperatures continued similar to those obtained by the "Porcupine," in the warm area.

We then proceeded to the north-eastward, and commenced running another sectional line parallel to the first and about eight miles N.E. from it. During the afternoon we obtained three soundings, two of which were in the cold area; the dredge was put over at 8 P.M. in 375 fathoms.

The day was fine but cloudy, slight swell from the eastward; the sun appeared at intervals and allowed us to determine our position with accuracy.

The dredge was hove up at 4 A.M. on the 29th July, and contained a few stones covered with serpulæ and gravel; some of the stones had on their upper surfaces a coating of peroxide of manganese, there were also a few sponges, ophiuroids, cephalopods, and gasteropods.

The sectional soundings were then continued, and three casts were taken in depths varying from 375 to 210 fathoms.

At 10 A.M. the weather, which had not been very favourable since the night before, changed for the worse, the barometer fell, and a fresh N.E. gale sprung up, which raised a high sea, and a portion of our bulwarks was carried away. It was deemed expedient to bear up for Stornoway, and we arrived at that port on Friday afternoon, after having spent a very unpleasant four and twenty hours.

Second Trip.

The weather having settled, the "Knight Errant" left Stornoway on the 3rd of August, and on the same day carried a line of soundings from the Butt of Lewis to Sulisker Island.

While off the Butt of Lewis, we stopped to shoot some of the sea-birds and to obtain some hauls of the tow-net in the locality where the birds were feeding, in order to ascertain, if possible, the nature of their food.

During the night we dredged in 53 fathoms. The day was very fine and bright, but towards evening a dark bank of clouds rose in the S.W., and the barometer began to fall. At 10 P.M. a drizzling rain commenced and lasted throughout the night.

On Wednesday the 4th August, we commenced running a sectional line of soundings N.N.W. from Rona Islands towards the last sounding obtained on the 29th July. We took nine casts of the lead, which, with one exception, were under 300 fathoms. At 6 P.M. we had completed the second sectional line. As the barometer was steadily falling, and the weather thick, with a long westerly swell, we proceeded towards Stornoway.

Third Trip.

The "Knight Errant" left Stornoway again on the 9th of August, with a rising barometer.

A line of soundings was carried out from the Butt of Lewis towards the "Holtenia ground" of Dr. Carpenter to the north-westward. During the night of the 9th we had a S.W. gale, which necessitated our "laying to."

On the 10th we sounded and trawled in 555 fathoms. There were many animals in the trawl. We had again to lay to in the evening on account of a moderate S.W. gale and thick weather.

On the 11th we sounded and trawled in 515 fathoms. This trawling was a somewhat barren one. As our observations showed us to be ten miles from the "Holtenia ground," we steamed to the northward, and trawled again in lat. 59° 37′ N., long. 7° 19′ W. The trawling here was rather more successful. We also obtained a serial temperature at every 50 fathoms down to 500 fathoms.

In the evening the dredge was put over for the night, the weather being fine.

On Tuesday the 12th, at 5 A.M., the dredge was hove up, and was found to be full of ooze, while to the tangles were attached numerous echini and starfishes. The ship's coal now running short we returned to Stornoway to replenish.

Fourth Trip.

We left Stornoway on Monday the 16th of August, and proceeded to Rona Island, carrying out a line of soundings. We stopped on the east side of Rona, and observing little break upon the shore, landed for a short time. The landing place is on the eastern side of the northern point of the island, where a narrow spur of moderate height projects from the higher land. It is at the entrance of a small cavern, faced by a series of natural steps, which were, in all probability, formerly used when Rona was inhabited.

The remains of a dwelling are visible in the immediate vicinity of the landing place.

The rock of Rona is composed of Laurentian gneiss, but here and there we gathered some fragments of Cambrian sandstone evidently washed up by the sea (see page 657). The power of the waves is here magnificently illustrated; all along the western side of this northern projecting point, at a height of over 50 feet above the level of the sea, is a line of stones, some of them of considerable size, which have evidently been forced up the face of the sloping cliffs during westerly gales.

The island is covered with rich turf, upon which were grazing a considerable number of sheep. There were numerous sea-birds on the cliffs, and several seals were seen near the shore.

On the western side of the projecting point on which we landed is a deep cavern, which extends to such a depth as to point to the probability of a breach being made in the not distant future which will separate the northern spur from the rest of the island.

During our stay off the island, several casts of the lead, over an uneven rocky ground, were obtained from the ship in 7 to 8 fathoms, with the extremes of Rona S. 38° W. and N. 54° W. (mag.).

On leaving Rona we proceeded to the cold area of the Faroe Channel. At 5 A.M., on the 17th August, we sounded in 540 fathoms, and put the trawl over.

At 10 A.M. the trawl was hauled in and contained a splendid lot of animals, fishes, cephalopods, starfishes, crustacea, sponges, pycnogonids, molluscs, &c.

A tow-net attached to the trawl contained some ooze. A serial temperature sounding was afterwards obtained at every 50 fathoms to the bottom.

For the next two days the ship was engaged in running lines of soundings between Rona Island, the Nun Rock, and Cape Wrath, and left Stornoway on Friday the 20th of August for the south.

We were unfortunate in having bad weather during all these cruises. This circumstance, together with the fact that the "Knight Errant" could not carry a large supply of coal, prevented our doing so much work as was originally intended.

Some most important results were, however, obtained.

IV. RESULTS.

1. *Observing Stations, &c.*—The following (pp. 650–51) is a list of the observing stations during the cruise of the "Knight Errant," with the position, depth, nature of deposit, bottom temperatures, and meteorological observations, with serial temperatures in the warm and cold areas.

The accompanying map of the Faroe Channel shows the soundings obtained by the "Knight Errant," in block figures, thus (**540**), while those formerly obtained are in ordinary Roman figures. The "cold" area is coloured blue, the "warm" area pink.

2. *Wyville Thomson Ridge.*—The most important result of the "Knight Errant" investigations was the discovery of the ridge predicted from theoretical considerations.

We have named the ridge "Wyville Thomson Ridge" in honour of the late Sir Wyville Thomson.

Its position is shown on the map by the contour lines of 300 fathoms. The exact height and form of the ridge, however, has still to be determined by a series of soundings in cross sections, and this work we hope to undertake during the present season.*

If we trust to the indications given by the serial temperature soundings, we should say that the depth over the ridge cannot much exceed 200 fathoms.

The discovery of this ridge is an important fact in Physical Geography, and is in itself a sufficient justification, if justification were needed, for a thorough reinvestigation of so highly interesting a region in such close proximity to our own shores. The discovery confirms strongly the correctness of the theory that submarine ridges exist in all cases in the ocean, between adjoining areas, the bottom temperatures of which differ materially at equal depths.

What is the Geological nature of the Wyville Thomson Ridge?—Is it an outcrop of ancient rocks like those of the north of Scotland? Is it of volcanic origin? Is it the remains of an ancient moraine? We have no very definite information on this point, but such as we have seems to indicate that the last supposition is the correct one. The two dredgings on the ridge—the one about mid-channel and the other at the north end of the ridge—both gave large stones,—Cambrian sandstone, diorite, micaceous sandstone, mica schist, gneissic rock, limestone, amphibolite, chloritic rock. These were all more or less rounded, and in some cases glacial markings could be detected. The assemblage of stones altogether resembled very much what we would expect to find in a moraine heap, such as would be formed from rocks found in the north of Scotland, rather than from those found in the Faroe Islands, which are volcanic.

We know of no agent at work at present in this region which could transport these stones to their present position. When lying on the bottom many of the stones projected above the deposit; and their

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* On the recommendation of the President and Council of the Royal Society of London, and the Hydrographer, the Lords Commissioners of the Admiralty have detached H.M. surveying vessel "Triton" for two months during this summer (1882), to complete the work commenced in the "Knight Errant."

No. of Sounding.	Date.	Time.	Position.		Depth in Fathoms.	Nature of Bottom.	Bot. Temp.		Meteorological Observations.							Remarks.
			Lat.	Long.			No. of Therm.	Reading of Therm.	Wind.	Force.	Weather.	Sea.	Barometer, unconnected.	Temp. Air.	Temp. Sea Surface.	
1	1880. July 27	5.5 a.m.	59° 15′ N.	6° 4′ W.	58	gravel	O, 2 O, 6	50°·0 50·8	E.N.E.	2	c.	mod.	29·818	54°·5	56°·2	
2	,, ,,	6.50 ,,	59 21 ,,	6 19 ,,	88	shells	O, 2 O, 6	49·5 50·2	E.N.E.	3	f.	mod.	29·800	54·5	57·0	
3	,, ,,	8.40 ,,	59 28 ,,	6 33 ,,	178	hard	O, 2 O, 6	49·6 50·2	E.N.E.	3	c.	mod.	29·800	54·5	56·2	
4	,, ,,	10.40 ,,	59 37 ,,	6 43 ,,	400	hard	O, 2 O, 6	45·8 47·2	E.N.E.	2	b.c.	mod.	29·800	55·5	57·8	
5	,, ,,	10.45 p.m.	59 44 ,,	6 55 ,,	560	grey ooze	O, 2 O, 6	45·2 45·8	E.N.E.	2	b.c.	mod.	29·832	55·5	57·5	
6	,, ,,	3.0 ,,	59 51 ,,	7 7 ,,	540	hard	O, 2 O, 6	46·0 46·5	E.N.E.	2	b.c.	mod.	29·832	54·0	54·0	
7	,, ,,	5.20 ,,	59 58 ,,	7 22 ,,	300	mud	O, 2 O, 6	47·5 48·5	E.N.E.	2	b.c.	mod.	29·832	52·5	55·0	
8	,, ,,	7.20 ,,	60 4 ,,	7 37 ,,	305	mud	O, 2 O, 6	46·5 47·7	E.N.E.	1	c.	mod.	29·030	52·0	54·8	Dredging Station No. 1.
9	,, 28	5.40 a.m.	60 3 ,,	7 52 ,,	405	ooze	O, 2 O, 6	46·5 47·0	E.N.E.	1	c.	mod.	29·760	51·0	54·0	
10	,, ,,	7.35 ,,	60 11 ,,	7 58 ,,	355	sand and coral	O, 2 O, 6	43·8 45·0	East	2	c.	mod.	29·760	51·0	53·0	
11	,, ,,	9.30 ,,	60 19 ,,	8 15 ,,	270	sand	O, 2 O, 6	43·5 45·0	East	1	b.c.	mod.	29·760	52·0	53·5	
12	,, ,,	11.15 ,,	60 25 ,,	8 28 ,,	335	sand and gravel	O, 2 O, 6	41·0 41·8	E.N.E.	2	b.c.	mod.	29·760	52·0	53·8	
13	,, ,,	1.0 p.m.	60 31 ,,	8 37 ,,	245	sand, gravel, and shells	O, 2 O, 6	41·8 42·5	E.N.E.	2	b.c.	mod.	29·760	51·5	53·0	
14	,, ,,	2.30 ,,	60 36 ,,	8 43 ,,	120	sand	O, 2 O, 6	47·5 48·0	E.N.E.	2	o.	mod.	29.760	51·0	52·5	
15	,, ,,	4.0 ,,	60 41 ,,	8 34 ,,	130	sand	O, 2 O, 6	46·0 47·2	E.N.E.	2	b.c.	mod.	29·750	51·5	52·0	
16	,, ,,	5.30 ,,	60 36 ,,	8 21 ,,	370	mud	O, 2 O, 6	33·5 34·0	E.N.E.	2	o.	mod.	29·760	51·0	52·5	
17	,, ,,	7.10 ,,	60 29 ,,	8 19 ,,	375	mud	O, 2 O, 6	31·0 31·0	E.N.E.	2	o.	mod.	29·760	51·0	53·0	Dredging Station No. 2.
18	,, 29	6.0 a.m.	60 26 ,,	8 17 ,,	375	mud	O, 2 O, 6	31·0 31·5	N.E.	4	o.c.	mod.	29·590	50·0	53·0	
19	,, ,,	8.0 ,,	60 20 ,,	8 3 ,,	285	gravel	O, 2 O, 6	32·5 33·6	N.E. by E.	4	o.c.	mod.	29·560	51·0	53·0	
20	,, ,,	9.45 ,,	60 15 ,,	7 49 ,,	210	hard	O, 2 O, 6	47·0 48·0	N.E. by E.	4	o.c.	mod.	29·560	51·0	53·0	

21	Aug. 4	5.15 a.m.	59 19 ,,	6 2 ,,	56	sand and shells	O, 2 O, 6	51·0 51·5	South	1	o.	mod.	29·710	55·0	54·5	
22	,, ,,	6.30 ,,	59 26 ,,	6 10 ,,	79	sand and shells	O, 2 O, 6	50·0 50·8	South	1	o.	mod.	29·710	55·0	55·0	
23	,, ,,	8.0 ,,	59 34 ,,	6 19 ,,	93	sand	O, 2 O, 6	50·0 50·8	South	1	o.	mod.	29·720	56·5	55·0	
24	,, ,,	9.30 ,,	59 41 ,,	6 28 ,,	145	sand	O, 2 O, 6	49·5 50·3	South	1	b.c.m.	mod.	29·720	56·5	55·5	
25	,, ,,	11.0 ,,	59 49 ,,	6 37 ,,	202	sand and gravel	O, 2 O, 6	48·2 49·0	South	1	b.c.m.	mod.	29·720	56·5	56·0	
26	,, ,,	0.30 p.m.	59 54 ,,	6 51 ,,	460	mud	O, 2 O, 6	46·0 47·0	South	1	m.	mod.	29·720	59·0	57·0	
27	,, ,,	2.0 ,,	59 59 ,,	6 47 ,,	255	gravel	O, 2 O, 6	48·0 49·0	South	1	m.	mod.	29·720	59·0	56·2	
28	,, ,,	3.30 ,,	60 02 ,,	7 4 ,,	285	sand and mud	O, 2 O, 6	45·8? 48·0	South	1	m.	mod.	29·720	59·0	56·5	
29	,, ,,	5.30 ,,	60 8 ,,	7 25 ,,	260	gravel	O, 2 O, 6	47·5 48·0	S.E.	3	m.	mod.	29·690	56·8	55·0	
30	,, 10	8.0 a.m.	59 33 ,,	7 14 ,,	555	mud	O, 2 O, 6	45·0 45·8	S.W.	3	o.p.q.	west'ly swell	29·99	66·0	57·0	Dredging Station No. 4.
31	,, 11	9.0 ,,	59 26 ,,	7 19 ,,	515	ooze	O, 2 O, 6	44·0 46·5	S.W. by W.	4	o.m.	,,	30·26	65·0	56·6	Dredging Station No. 5.
33	,, 17	4.45 ,,	60 3 ,,	5 51 ,,	540	ooze	O, 2 O, 6	28·0 30·5	N.N.E.	1·2	o.	smooth	30·40	57·0	56·5	Dredging Station No. 8.

Serial Temperatures.

32	Aug. 11	p.m.	59 37 N.	7 19 W.	530	ooze	...	...	S.W.	2	o.f.	mod.	30·32	59·0	57·0	Dredging Stations Nos. 6 and 7.
					surface			57·0								
					50		21	49·0								
					100		23	50·0								
					150		O, 6	48·8								
					200		O, 2	48·0								
					250		21	49·2								
					300		22	48·6								
					350		0	48·0								
					400		O, 6	47·5								
					450		23	47·2								
					500		O, 2	46·5								
33	,, 17	a.m.	60 3 ,,	5 51 ,,	540	ooze	...	...	N.N.E.	1·2	o.	smooth	30·40	57·0	56·2	
					surface			56·2								
					50		O, 2	49·2								
					100		O, 6	48·2								
					150		0	47·5								
					200		21	48·0								
					250		22	47·0								
					300		23	40·5								
					350		21	36·8								
					400		22	31·5								
					450		23	30·5								
					bottom	...	O, 2 O, 6	28·0 30·5								

upper surfaces were covered with a coating of peroxide of manganese, and had living serpulæ attached. The line to which a stone was imbedded in the deposit was sharply marked by the manganese deposit. It would seem as if currents existed here towards the north-east strong enough to carry fine mud away from the top of the ridge, and to leave the larger stones exposed, or at least strong enough to prevent a deposit of fine mud from forming.

It is worthy of remark that we dredged no large stones in either the cold or warm area, some distance away from the ridge.

In the deposit of the warm area the average size of the mineral particles is only ·15 m.m., and these are nearly all angular fragments of quartz, fellspar, &c., but no fragments of the ancient rocks of the north of Scotland of sufficient size to be detected. In the cold area the mean diameter of the mineral particles is ·35 m.m., with many larger fragments of Cambrian (?) sandstone, mica schist, amphibolic gneiss, &c. (see description of deposits, pages 29–33).

3. *Temperature.*—The serial temperatures show that from the surface to a depth of a little over 200 fathoms the temperature of the water is nearly the same over both the warm and cold areas, but at greater depths there are wide differences.

Similar results were obtained by the "Porcupine" in 1869.

It is very probable that throughout the winter, the temperature at the sea surface and to the depth of 200 fathoms in this vicinity, is from 48° to 49°. This temperature is much warmer than that found in the same latitude in any other part of the North Atlantic. It is evidently, therefore, not derived from the locality or from a more northern source, but certainly comes from a southern latitude.

For these reasons we believe that the whole body of water on the south-western side of the Wyville Thomson Ridge is moving toward the north-eastward, and that the layers deeper than 200 fathoms are stopped or deflected, when they come in contact with the ridge, while those less deep than 200 fathoms flow onward to the north-eastward.

The cold water, which fills the deeper part of the basin to the N.E. of the ridge, must come from the Arctic Ocean.

Here we would point out a peculiarity in the distribution of temperature in the Faroe Channel, a peculiarity not met with in any of the regions examined during the "Challenger" expedition.

In the diagram (fig. 1) given on page 5, we have represented that the basin on the right is filled with water of a uniform temperature, which is believed to have flowed over the top of the ridge (A), so that the minimum temperature in this basin is found at a depth the same as that over the top of the submarine ridge.

In the Faroe Channel, however, as is shown in the diagram here given (fig. 2), although the water on the one side of the ridge is warmer, at depths exceeding 200 fathoms, than that on the other side, yet on both sides of the ridge the *minimum temperature is only reached at the bottom;* the water in the right hand basin cannot, therefore, have passed over the ridge, as in the case illustrated by diagram fig. 1. Indeed we have shown that the cold water at the bottom of the N.E. basin must come from the Arctic Ocean or Spitzbergen Sea.

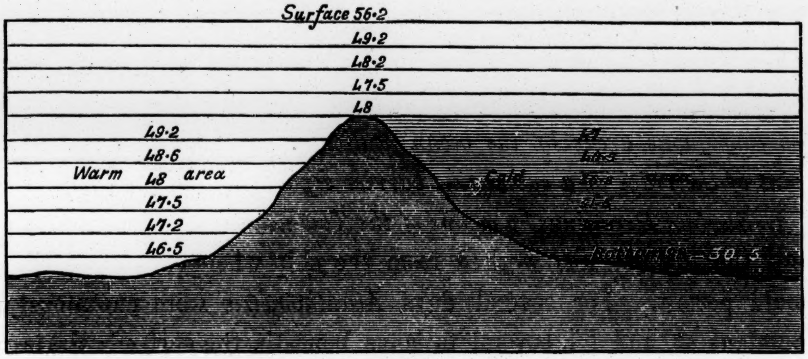

Fig. 2.

Along the whole eastern side of the Atlantic, from the island of Teneriffe to the Faroe Islands, the isotherm of 40° is at a depth of no less than 900 fathoms from the surface. If we except the enclosed areas of the Mediterranean, Red Sea, and Sulu Sea, this is the only part of the world where so high a temperature is found at so great a depth.

It is owing, doubtless, to the comparative shallowness of the water, that the minimum temperature on the Atlantic side of the Wyville Thomson Ridge is so high. We have every reason to believe that if the depth here exceeded 2000 fathoms the minimum temperature would be 36·5°, as in the whole eastern basin of the Atlantic.

What becomes of the underflow of cold arctic water shown by the shaded portion of the above diagram (2)? Does any of it pass over the ridge to the west? What becomes of the excess of this cold water? At present we can give no satisfactory answer to this question. A discussion on this point may appropriately be deferred till the further observations and more detailed investigations which it is proposed to undertake during the present season have been completed.

Bearing in mind the peculiarity pointed out above as existing in the Faroe Channel, the doctrine of submarine barriers may be stated in more general terms than those used on page 4, as follows:—*A divergence of temperature between the deep waters of two contiguous areas of the ocean indicates the level of the lowest point of the ridge of a submarine barrier separating the two areas.*

4. *Surface Dredgings by means of the Tow-net.*—During each of the trips the tow-net was worked from the ship whenever the weather would permit. For several days *Acanthometræ* were enormously abundant at, and for several fathoms beneath, the surface: during our last trip to the cold area very few of them were met with. Pelagic foraminifera had never been taken near the British Islands, but relying on our "Challenger" experience, we predicted that they would be captured in the tow-net so soon as the water beyond the Butt of Lewis was reached. Our anticipations were realised. So soon as we got into true oceanic waters globigerinæ were procured in considerable abundance at the surface. Orbulinæ were rare, and we only noticed one *Pulvinulina micheliniana.* All these specimens were dwarfed, and quite similar to the dead shells found at the bottom both with regard to their size and relative frequency. These observations were quite in accordance with those made by the "Challenger" in various parts of the world. The occurrence of these surface forms in the deposits of the cold area shows that the upper layers of water are passing to the north-east; while *Globigerina borealis*, which we believe to be an arctic surface species, does not apparently occur in the warm area deposits, this would seem to show that the arctic water does not pass over the ridge to the south-west.

On one occasion, several miles off the Butt of Lewis, we spent some hours in examining a portion of the sea where numerous puffins, gannets, razorbills, and other birds were feeding, one of those places, in short, where fishermen go to shoot their herring nets, guided by the presence of the birds and other animals. Here, within one or two fathoms of the surface, the tow-net gave only a few Copepods, Diatoms, and Echinoderm larvæ. When, however, the tow-net was dragged at a depth of from 7 to 10 fathoms, it came up filled and covered with a mass of beautiful yellow or orange-coloured slime. This, on examination, was found to be composed of immense multitudes of *Peridinium tripos.* We may remark that none of these were *in catena;* whereas in the open ocean and more southern latitudes, these organisms are frequently met with in chains consisting of nine or ten individuals. Although these *Peridinia* are often regarded as flagellate infusorians, yet we could never detect either a flagellum or cilia, though we have observed them for several years. Indeed they seem to be undoubted algæ, and their production in enormous abundance most probably depends on certain conditions of sunlight and temperature. Another haul of the tow-net at a depth exceeding 10 fathoms, gave vast numbers of the *megalopa* stage of crabs, together with a good many Copepods, Amphipods and larval fish. The stomachs of these Crustaceans were filled with Peridinia, so that these minute Algæ supplied them with food. The herring and mackerel, which we procured from the fishermen, had their stomachs filled with these minute Crustaceans. The birds, again, were feeding upon the herring. Dolphins, whales, and dog fish were also busy upon the same ground, but, unfortunately we had no opportunity of examining their stomachs.

We have here a chain of phenomena, which if carefully worked out, might give much information concerning the habits of many of our food fishes. The abundance of *Peridinia* gives food for the minute animals which are in a process of development in the ocean, and these again serve as food for our edible fishes. A knowledge of the food supply of these fishes, indeed, and of the conditions to which it is subject, would probably give the key to the solution of the mystery which at present surrounds the migrations of many of these fishes. That knowledge can best be acquired by a diligent and continued use of the tow-net, together with an examination of the stomachs of the fish. In the stomach of the herring and mackerel which we examined during our cruises the following were observed:—Young of herring, sprat and other fish, *Zoeas* of crabs, *Galathea, Algæ, Mysis, Euphausia, Thysanopoda, Hyperia, Cythere, Lemora, Evadne, Larvæ* of Molluscs, *Sagitta.* The Schizopods were sometimes very numerous in the stomachs.

Dr. James Rae, R.N., gives the following list of Diatoms from the "Knight Errant" surface gatherings:*—

Coscinodiscus concinnus.
,, *radiatus.*
,, *oculus iridis.*
Campylodiscus costatus.
Hemidiscus cuneiformis.
Rhizosolenia, sp. (?).
Chetoceras, sp. (?).

Professor Ernst Haeckel gives the following list of Radiolaria:—

Acanthometra.
Xiphacantha.
Dorataspis.
Ethmosphaera.
Heliosphaera.
Rhizosphaera.
Actinomma.
Spongocyrtis.
Thalassicolla.
Calcaromma.
Actinocyrtis.
Amphilonche.
Spongodiscus.
Thalassosphaera.

Dr. George Brady gives the following list of Copepoda and Cladocera:—

Oithona spinifrons ?	Boeck.
Calanus finmarchicus.	Gunner.
Temora longicornis.	Müller.
Dias longiremis.	Lilljeborg.
Eucalanus attenuatus.	Dana.
Centropages typicus.	Kroyer.
Anomalocera patersonii.	Templeton.
Evadne nordmanni.	
Pleopis polyphemoides.	Lovén.

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* In a letter Mr. E. Grove gives me the following additional diatoms from the "Knight Errant" surface gatherings in the Faroe Channel:—

Hyalodiscus maculatus.	(Podosira, W.S.)
Coscinodiscus centralis.	(1 specimen only.)
Melosira sulcata.	(scarce.)
Actinophychus undulatus.	(1 specimen only.)
Actinocyclus ehrenbergii.	(1 fragment.)
Biddulphia mobiliensis, Bail.	(scarce.)
Rhizolenia styliformis.	(frequent.)
,, alata.	(not unfrequent.)
,, imbricata ? var.	(scarce.)
Chœtoceras decipiens ? Cleve.	(common.)
(? Chœt. bacillaria, Bailey.)	
Chœt. boreale, Bail.	(scarce.)
,, var. brightwellii, Cleve.	(frequent.)
Navicula distans.	(1 specimen.)
Pleurosigma directum, Grun.	(frequent.)
(Scarcely sigmoid, has apppearance of a Navicula.)	
Synedra thalassiothrix, Cleve.	(frequent.)

In addition to the above the following were observed :—

Globigerina bulloides. *Globigerina inflata.* *Orbulina universa.* *Pulvinulina micheliniana* (one).	See Mr. H. B. Brady's Report.

Salpæ, Sagittæ, Schizopods, Amphipods, larvæ of *Membranipora*, Lamellibranch, Gasteropod and Echinoderm larvæ, *Peridinium tripos*, and Coccospheres.

5. *Dredgings, Trawlings, and Soundings.*—For convenience of reference and comparison we divide these into (*a*) those on the plateau surrounding North Rona and Sulisker, (*b*) those in the warm area, (*c*) those in the cold area, and (*d*) those on the Wyville Thomson ridge.

(*a*.) *On the Plateau surrounding North Rona and Sulisker.*

(1) *Soundings.*—A great many soundings were taken on the plateau which surrounds North Rona, and between it and the Butt of Lewis and Cape Wrath. The depths were from 30 to 80 fathoms, the average being about 50 fathoms.

The bottom was sometimes a fine calcareous sand, sometimes a quartz sand, and sometimes a fine gravel. These varieties of deposits occurred without any apparent relation to depth. Generally the particles were more or less rolled, and all the materials collected on this plateau out to the 100 fathom line, gave the impression that they were often set in motion and frequently sorted by the action of waves and currents. None of the soundings indicated the presence of mud or argillaceous matter.

The calcareous particles were composed of broken and rolled fragments of mollusc shells, polyzoa, Annelid tubes, echinoderms and foraminifera.

The sandy particles were chiefly rounded fragments of quartz, with some pieces of mica, hornblende, and feldspar.

The gravel was composed of rolled pieces of the older rocks, as amphibolic gneiss, Cambrian sandstone, diorite, and pieces of jasper.

The following were the percentages of carbonate of lime in four of these soundings :—

S.S.W. of North Rona	3rd August.	53 fathoms.	80·15 per cent.
	3rd „	59½ „	31·54 „
W. of North Rona	18th „	43 „	77·00 „
	18th „	54 „	22·61 „

(2) *Dredgings.*—Two hauls of the dredge were taken N.N.W. of North Rona on the 3rd and 4th August 1880. Lat. 59° 12′ N., long. 5° 57′ E., in 53 fathoms.

1st haul.—The dredge was lowered at 5.30 P.M. and hauled in again at 8 P.M., it had two swabs and a tow-net attached. The bag of the dredge and the tow-net attached were filled with sand and gravel, and several echini, starfish, ophiurids, polyzoa, lamellibranchs, annelids, hydroids, and attached foraminifera.

2nd haul.—The dredge, with swabs, was put over at 9.30 P.M. on the 3rd, and hauled in at 3.30 A.M. on the morning of the 4th August. The bag of the dredge was burst, or rather the lower surface had been torn away by passing over rough ground, one swab was carried away, and the other was covered with polyzoa. In the dredge and on the swab were several starfish, one comatula, ophiurids, crustacea, gasteropods, and lamellibranchs, many polyzoa, cirripeds, pycnogonids, sponges, hydroids, and attached foraminifera.

The largest pieces of rock were about 4 centimetres in diameter, and all the fragments were more or less rounded.

The following were the principal varieties of rocks observed :—

1. Mica-schist, composed of alternate bands of feldspar and quartz with mica.
2. Quartzite.
3. Micaceous quartzite (Cambrian?).
4. Red micaceous sandstone.
5. Limestone.
6. Syenitic rock containing feldspar and hornblende, quartz, passing to amphibolite.
7. Large grained sandstone (Cambrian?), containing feldspar.
8. Arkose, containing quartz, feldspar, and Muscovite.

The sand is composed of grains of quartz, more or less rounded, feldspar grains are much less abundant, hornblende, small fragments of rocks, quartzite, sandstone, amphibolite. The sand seems to come from the decomposition of granite and gneiss. It is strange, however, that mica appears to be quite absent. We subjoin a list of the animals obtained.

Mollusca.

Circe minima.	Montagu.
Venus fasciata.	Da Costa.
Tapes virgineus (young).	Linné.
Tellina crassa.	Gmelin.
Psammobia costulata.	Turton.
Mactra solida, var. (*elliptica*).	L.
Saxicava rugosa, var. (*arctica*).	L.
Eulima polita.	L.
Natica montacuti (*montagui*).	Forbes.
Aporrhaïs pes-pelecani.	L.

Asteroidea.

Luidia sarsii.	Düb. & Kor.
Porania pulvillus.	O. F. Müll.
Cribrella oculata.	Linck.
Crossaster papposus.	Linck.
Asteracanthion rubens.	Linné.
,, *mülleri.*	Sars.

Crustacea.

Stenorhynchus longirostris.	Fabr.
Hyas coarctatus.	Leach.
Ebalia tuberosa.	Pennant.
Munida rugosa.	Fabr.
Ligia oceanica.	
Eurydice truncata.	Norman.
Scalpellum vulgare.	Leach.
Balanus.	

Pycnogonida.

Pycnogonum littorale.	Ström.

Annelida.

Lagisca propinqua.	Mgn.
Evarne, n.s.p.	
Glycera capitata.	Œrsted.
Onuphis bilineata.	Baird.
Lumbriconereis fragilis.	O. F. M.
Ditrypa arietina.	O. F. M.
Serpula vermicularis.	L.

Echinoidea.

Echinus norvegicus.	Düb. & Kor.
,, *acutus.*	Lamk.
,, *melo.*	Lamk.
Echinocyamus pusillus.	Gray.
Spatangus purpureus.	Leske.
Echinocardium flavescens.	A. Ag.
,, *pennatifidium.*	Norm.

Ophiuroidea.

Ophiocoma nigra.	Müll. and Tr.
Ophiopholis aculeata.	Gray.
Ophiothrix pentaphyllum.	Ljn.

Hydroida.

Thuiaria thuia.
Tubularia indivisa.
Other Hydroids.

Porifera.

Tetilla cranium.	Müll.

Crinoidea.

Antedon rosacea.	

Polyzoa.

Bugula flabellata.	J. V. T.
,, *plumosa.*	Pallas.
Flustra foliacea.	Linn.
Cellepora ramulosa.	Linn.
Cellepora avicularis.	Hincks.
Eschara compressa.	Sowerb.
Retepora beaniana.	King.
Salicornaria farciminoides.	Solander.
Lepralia unicornis, var. *ansata.*	
Porella levis.	Fleming.

(*b.*) *Soundings, Dredgings, and Trawlings in the Warm Area.*

Sounding No. 5 and dredging stations 4, 5, 6, and 7 are all in the warm area, and are all within a few miles of each other. The depths are nearly the same, and the general character of the deposit in each case is similar.

Station 4. 10th August. 555 fathoms. Lat. 59° 33′ N., long. 7° 14′ W. Bottom temperature, 44·4°; surface temperature, 57·0°.

A small quantity of a grey calcareous mud came up in the sounding tube. Trawl without swabs or tow-nets was used. It was put over at 8.30 A.M., and hauled in at 11.30 A.M. There were in it several fish, several hundred holothurians, crustacea, annelids, &c., as follows:—

Pisces.

Chimæra monstrosa.	L.
Cottus thomsonii, n. sp.	
Haloporphyrus lepidion.	Risso.
Macrurus, sp. n. (probably young of *M. trachyrhynchus*).	

Echinoidea.

Phormosoma uranus.	Wyv. Thom.
,, *placenta.*	,, ,,

Asteroidea.

Mimaster tizardi, n. gen. and sp.	

Actinia.

Actinia.	

Holothurioidea.

Lætmogone violacea (about 300 specimens).	Théel.
Stichopus (?) *tizardi*, n. sp.	

Crustacea.	
Munida tenuimana.	G. O. Sars.
Nephropsis atlantica, n. sp.	
Annelida.	
Empty chitinous tube.	

Station 5. 11th August. Lat. 59° 26′ N., long. 71° 19′ W. 515 fathoms. Bottom temperature 45·4°; surface temperature, 56·6°.

The trawl had a tow-net attached to the beam, but without swabs, and without a bag in the bottom of the trawl. It was put over at 9 A.M., and hauled in at 11.30 A.M.

The tow-net came up with a small quantity of mud, some surface organisms, and in the trawl there were some crustacea, holothurians, and annelids, &c., as follows:—

Mollusca.	
Fusus sarsi (young).	Jeffreys.
Holothurioidea.	
Lætmogone violacea.	Théel.
Crustacea.	
Dorhynchus thomsoni.	Norman.
Amathia carpenteri.	Norman.
Munida tenuimana.	G. O. Sars.
Pycnogonida.	
Nymphon strœmii.	Kröyer.
Annelida.	
Evarne johnstoni.	M'Intosh.
Nemerteans (*Enopla* and *Anopla*).	
Crinoidea.	
Rhizocrinus lofotensis.	M. Sars.
Ophiuroidea.	
Ophiacantha tridentata.	Ljn.
Echinoidea.	
Echinus (?).	

Stations 6 and 7. 11th August. 530 fathoms. Lat. 59° 37′ N., long. 7° 19′ W. Bottom temperature, 46·5°. Surface temperature, 57·0°.

1st haul.—No sounding was taken, the position being the same as that of a "Porcupine" station in 1869, giving a depth of 530 fathoms.

The trawl was put over at 2 P.M., and hauled in at 6.30 P.M. with tow-net attached to the beam, but no bag in the bottom of the trawl nor swabs were used. In the tow-net there was a little of the deposit evidently knocked up by the action of the trawl in passing over the bottom, and in the trawl were many animals.

2nd haul.—Dredge with two swabs attached was put over at 8 P.M. on the 11th, and hauled in at 4 A.M. on the 12th August. The bag of the dredge was full of a grey mud (about 40 litres) with Echinoderms, Annelids, Gasteropods, &c.

*Description of the Deposit.**

GREY MUD coherent, finely granular, homogeneous, earthy, calcareous, has a greenish tinge when wet.

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* The description of these deposits has been made upon the plan which we have adopted in our work in preparation upon the oceanic deposits, to form one of the reports on the scientific results of the "Challenger" expedition.

This is not the place to develop the reasons which have guided us in adopting this mode of description, or to expose, in detail, the methods which we have systematically employed for all the sediments which we are engaged in describing. These will be given in great detail in the introduction to our "Challenger" report. We limit ourselves here, in order to facilitate the comprehension of our descriptions, to describe the order of our tables, and to explain the meanings and arrangement of terms and abbreviations.

The description commences by indicating the kind of deposit (red clay, grey mud, globigerina ooze, &c.), and comprises the microscopic determination of the characters of the deposit, when wet or dry.

When we have not given a complete analysis of the deposit, we have always determined the amount of CARBONATE OF CALCIUM. This determination was generally made in estimating the carbonic acid. We took usually, for this purpose, a gram of the substance, and calculated in this manner the carbonate of calcium. Weak and cold hydrochloric acid was used. However, as, independent of the carbonate of calcium, the deposits often contain carbonates of magnesia and iron, the results calculated in placing the carbonic acid to CaO are not perfectly exact. These carbonates of magnesia and iron are almost always in very small proportion, and the result of the process gives that degree of accuracy which we think necessary. The number which follows the words "carbonate of calcium" indicates the percentage of $CaCO_3$; we then give the general designations of the principal calcareous organisms forming the carbonate of lime in the deposit. The part insoluble in the acid, after the determination of the carbonic acid, is designated in our descriptions by the name RESIDUE. The number which follows this word indicates its percentage in the deposits; then follow the colour and principal physical properties. This residue is washed and submitted to regular decantations, which permit the several elements of this insoluble portion being separated according to their density. We divide these portions into three groups—(1) *Minerals*, (2) *Siliceous Organisms*, (3) *Fine Washings*.

1. *Minerals.*—The number within brackets indicates the percentage of particular minerals and fragments of rocks. This number is the result of an

CARBONATE OF CALCIUM 32·72 per cent., consists of Coccoliths, Coccospheres, Globigerinas, Pulvinulinas, Orbulinas, Nodosarias, Truncatulinas, Nonioninas, &c. Fragments of Echini, Molluscs, Ostracodes, one or two Pteropod fragments.

RESIDUE 67·28 per cent., greyish-brown, consists of—

Minerals [40·00], m. di. 0·1 mm., almost all angular; quartz, hornblende, augite, magnetite, volcanic glass, glauconite, feldspar.

Siliceous organisms [5·00]: Diatoms, Radiolarians, Sponge spicules, and a few glauconitic casts of Foraminifera.

Fine washings [22·28]; argillaceous matter with minute fragments of minerals and siliceous organisms.

Remarks.—The larger portion of the mud was passed through fine

approximate valuation, of which we will give the basis in our report. As it is important to determine the dimensions of the grains of minerals which constitute the deposit, we give, following the contraction *m. di.*, their mean diameter in millimetres. This evaluation is made with the micrometer. We give next the form of the grains, if they are rounded, &c., then follows the enumeration of the species of minerals and rocks. In this enumeration we have placed the minerals in the order of the importance of the rôle which they play in the deposit. The specific determinations have been made with the microscope, and with the aid of Nicol's prisms, by parallel or convergent light.

2. *Siliceous Organisms.*—The number between brackets indicates the percentage of siliceous organic remains. We obtain it in the same manner as that placed after the word *Minerals.* The siliceous organisms and their fragments are examined with the microscope. We have also placed under this heading the glauconitic casts of the foraminifera and other calcareous organisms.

3. *Fine Washings.*—We designate under this name the particles which, resting in suspension, pass with the first decantation. They are about 0·05 mm. or less in diameter. We have not been able to arrange this microscopic matter under the category of *Minerals,* because at this small size it is impossible to determine the species. We have always found that the *Fine Washings* is in considerable quantity as the deposit passes to a clay, and it is from this point of view that the subdivision has its *raison d'être.* We often designate the lightest particles by the name argillaceous matter, but usually there are associated with this very small fragments of indeterminable minerals, and fragments of siliceous organisms. The number within brackets which follows the words *Fine Washings* is obtained in the same manner as the similar numbers referred to in the two preceding paragraphs.

These few words will suffice to render our descriptions intelligible. Greater details will be given, as already stated, in our larger work. We may add that in the majority of cases we have solidified the sediments and formed them into thin slides for microscopic examination, and that at all times the examination by transmitted light has been carried on at the same time as the examination by reflected light. Each description is followed by notes upon the dredging or sounding, upon the animals collected, and a discussion of the analysis whenever a complete analysis has been made.

J. M. and A. R.

sieves, and the washings thus obtained consisted of sandy and calcareous Foraminifera, small Gasteropod and Lamellibranch shells, a few fragments of Pteropod shells, worm-tubes, sponge spicules, a few Radiolaria, and grains of quartz.

When the mud itself is passed between the finger and thumb small hard particles are felt.

Chemical analysis gave the following :—

From Station 4. Sounding tube. 555 fathoms.

Insoluble in HCl,	. . . . . .	69·43
Soluble in HCl	$Al_2O_3 - Fe_2O_3$, . .	1·17
	$CaCO_3 - MgCO_3$, . .	28·96
		99·56

Microscopically examined, the carbonate of calcium appears to make up fully one-half of the deposit in bulk, and consists almost entirely of the dead shells of Globigerina, Pulvinulina, and Orbulina, along with Coccoliths and Coccospheres, which have fallen from the surface to the bottom. Many other genera of Foraminifera, as Textularia, Uvigerina, Nonionina, Truncatulina, Nodosaria, &c., together with fragments of Polyzoa, Echinoderms, Gasteropods, Lamellibranchs, Pteropods, and Cypridina valves were observed, but these do not seem to make up more than 2 per cent. of the total quantity of carbonate of lime in the deposit.

The insoluble residue is essentially composed of grains of quartz, often covered with hydrate of iron, and having a diameter of ·5 mm., associated with these are many black particles, which may be extracted by the magnet and are magnetic iron, while others are particles of mica and hornblende.

There are numerous glauconitic casts of Foraminifera and other organisms of a yellow and greenish tinge; radiolarians and sponge spicules are also present.

When the deposit is hardened and made into thin microscopic slides, it can be observed that the quartz is of clastic origin, and generally rounded or of an irregular shape, the black mineral particles are seen to be transparent, green, dicroscopic, and formed of biotite. The magnetic iron and hornblende particles are much less abundant than the mica, one rarely sees the cleavage characteristic of hornblende; some small particles of a blue colour, very dicroscopic, might be referred to tourmaline; some of the arenaceous Foraminifera are uniformly coloured red.

List of the Animals taken at these Stations.

Pisces.

Haloporphyrus lepidion.	Risso.	Stat. 6.
Brosmius brosme.	Müll.	,,

Mollusca.

Amussium hoskynsi.	Forbes	,,
Aporrhaïs serresianus.	Michaud.	,,
Fusus fenestratus.	Turt.	,,
Fusus berniciensis, var. (*elegans*).	King.	,,
Arca pectunculoïdes.	Sc.	Stat. 7.
Leda lucida.	Lov.	,,
,, *frigida.*	Torell.	,,
Nucula tumidula.	Malm.	,,
,, *corbuloïdes.*	Seguenza.	,,
Cardium minimum.	Ph.	,,
Neæra striata.	Jeffr.	,,
,, *obesa.*	Lov.	,,
Hela tenella (young).	Jeffr.	,,
Natica montacuti (young).	Forbes.	,,
Aporrhaïs serresianus (young).	Mich.	,,
Cerithium metula.	Lov.	,,
Columbella haliæeti.	Jeffr.	,,
,, *costulata.*	Cant.	,,
Cylichna alba.	Brown.	,,
,, *ovata.*	Jeffr.	,,

Echinoidea.

Spatangus purpureus (young) ? ?	Leske.	Stat. 6.
Phormosoma placenta.	W. Th.	,,
Porocidaris purpurata.	W. Th.	Stat. 7.
Dorocidaris papillata.	A. Ag.	,,
Echinus norvegicus.	Düb. & Kor.	,,

Ophiuroidea.

Ophioglypha aurantiaca.	Vll.	Stat. 6.
Ophiactis abyssicola.	Ljn.	Stat. 7.

Holothurioidea.

Lætmogone violacea.	Théel.	Stat. 6.
Thyone raphanus.	Düb. and Kor.	Stat. 6 & 7.
Stichopus (?) *tizardi.* .	n. sp.	Stat. 6.
Echinocucumis typica.	Sars.	Stat. 7.

Crustacea.

Geryon tridens.	Kröyer.	Stat. 6.
Munida tenuinana.	G. O. Sars.	Stat. 6 & 7.
Amathia carpenteri.	Norman.	Stat. 7.
Eurydice polydendrica.	N. & Stebbing.	,,
Haploops setosa.	Boeck.	,,
Ampelisca compacta.	n. sp. (?)	,,

Pycnogonida.

Nymphon strœmii.	Kröyer.	

Annelida.		
Nothria (small).		Stat. 6
Empty muddy tubes.		,,
Aphrodita aculeata.	L.	Stat. 7.
Lætmonice filicornis.	Kbg.	,,
Leanira hystricis.	Ehlers.	,,
Maldane, near *sarsi.*	Mgn.	,,
Ampharete arctica.	Mgn.	,,
Hydroides norvegica.	Gunn.	,,
Protula (fragt.).		,,
Asteroidea.		
Archaster bifrons.	Wyv. Thom.	,,
Astropecten andromeda.	Müll. & Tr.	,
Porifera.		
Holtenia, sp.?		
Crinoidea.		
Rhizocrinus, fragt.		,,
Pennatulida.		
Kophobelemnon mülleri (?)	Sars.	Stat. 6 & 7.
Pennatula rosacea.		Stat. 7.
,, sp.		

Sounding 5. 27th July 1880. Depth, 560 fathoms.

Grey mud with slight greenish tinge, plastic, granular, calcareous, earthy, with small hard particles.

Carbonate of calcium 27·36 per cent., consists of Coccoliths, Coccospheres, Globigerinas, Pulvinulinas, Uvigerinas, Cassidulinas, Nonioninas, Nodosarias, &c., fragments of Echini, Ostracode valves.

Residue 72·64 per cent., brownish-grey, consists of—

Minerals [55·00], m. di. 0·15 mm., a few particles nearly ·5 mm.; quartz, hornblende, mica, feldspar, glauconite. The quartz grains are often rounded, the other particles are angular.

Siliceous organisms [2·00]: Diatoms, spicules of Sponges, and casts of Foraminifera of a pale yellow-green colour.

Fine washings [15·64]; argillaceous matter with fragments of siliceous organisms and minute mineral particles.

(*c.*) *Dredgings and Trawlings in the Cold Area.*

Station 8. 17th August. 540 fathoms. Lat. 60° 3′ N., long. 5° 51′ W. Bottom temperature, 29·2°. Surface temperature, 56·5°.

In the sounding tube there was a small quantity of blue mud.

The trawl was used with a swab at one end and a tow-net at the other end of the beam, and a bag at the bottom of the netting. In the tow-net there was about a litre of mud, and about 5 litres in the bag of the trawl. In the trawl there were, besides many hundreds of pycnogonids, many fish, some starfish, ophiuroids, echini, &c.

BLUE MUD with greenish tinge, grey when dry, sandy, calcareous.

CARBONATE OF CALCIUM 12·75 per cent., consists of many Coccoliths and Coccospheres, Globigerinas, Pulvinulinas, Nonioninas, Lagenas, &c., fragments of Echini, Ostracodes, Molluscs.

RESIDUE 87·25 per cent., consists of—

Minerals [65·00], m. di. ·3 mm., with some particles over 1 mm., often rounded; quartz, often covered with oligist, augite, hornblende, magnetite, mica, fragments of ancient and recent rocks.*

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* We will not seek here to justify in detail the employment of the terms *ancient* and *recent* rocks, but limit ourselves to indicating the meaning which we give to these terms, and the reasons which have guided us in introducing into our descriptions this subdivision of massive crystalline rocks into two groups. This is not the place to enter into the discussion, which is being carried on at the present time among a certain number of lithologists, as to whether the same denomination ought to be applied to the same lithologic type without respect to its geological position.

Whatever may be the issue of these discussions, it remains, nevertheless, true, that there exist certain minute details of structure, and certain characters in the constituent minerals of rocks, differences, in short, sufficiently important to indicate generally if a massive crystalline rock belongs to ante-tertiary or tertiary and post-tertiary periods. If, as we think, these two groups can be practically distinguished, even although they present insensible transitions from one to the other, then it is important, for an exact knowledge of the origin of sediments, to take this division into consideration in our descriptions of marine deposits. These sediments we know include at the same time rocks and free minerals produced by the disintegration of these rocks. If we are able to apply the distinction into ancient and recent rocks, then we ought, in a certain sense, to be able to tell whether the isolated minerals found in the deposit come from the one or the other type of rock. We should be able, by the aid of this distinction, to determine with probability whether the mineral fragments found in deposits come from continents, are the result of submarine eruptions, or have been carried by floating ice, &c.

Notwithstanding the care which has been taken to establish these distinctions, we are often unable to pronounce with certainty; for, as we have said, the distinctive characters which we have alluded to are not so well marked, the fragments which are present in the deposits are very minute, and many of the finer details have been removed by decomposition. As to the minerals, with which we have more frequently to deal than with the rocks them-

Siliceous organisms [3·00]: Sponge spicules, Diatoms and Radiolarians, and one or two pale glauconitic casts.

Fine washings [19·25]; argillaceous matter with minute fragments of minerals, diatoms, and other siliceous organisms.

Remarks.—When the mud is passed between the fingers many gritty particles are found to be present. These can be observed generally to be fragments of quartz and rocks.

Chemical analysis gave the following:—

Insoluble in HCl,	. . . . . .	84·55
Soluble in HCl	$Al_2O_3 - Fe_2O_3$, . .	1·22
	$CaCO_3 - MgCO_3$, . .	14·34
		100·11

The carbonate of lime appears to make up about one-fourth of the deposit in bulk, and consists almost wholly of pelagic Foraminifera, Coccoliths, and Coccospheres, the same as found at the stations in the warm area.

Mixed up with these are a few of the bottom living Foraminifera and fragments of Echinoderms. The insoluble residue is essentially

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selves, the difficulty is still greater, on account of their isolated condition and the physico-chemical actions which they have undergone. However, we are often aided by their association with fragments of rock, whose classification is possible; by their being sometimes seen, on microscopic examination, to be bordered by remains of the rock of which they were formerly an integral part; and by their geographical position (which point is also applicable to the determination of the age of fragments of rocks). Whatever we may think of the causes of the characteristic differences of these two lithologic groups, this distinction offers, none the less, a very practical advantage, and if it is applied with care, it throws some light on the interpretation of the facts with which we have to deal.

We cannot dwell, in this note, upon the diagnostic characters which we have employed; we will return to that in the introduction to our Report on the deposits collected during the "Challenger" expedition. As we have had, especially, to study very minute fragments of rocks and of isolated minerals, questions relative to the structure of rocks, properly so called, have been considered only in a subsidiary manner. We give some of the characters which have guided us in the classification into the two groups. We repeat that these peculiarities have only a relative value, and we do not regard them as absolutely conclusive in every case.

We may add that it is especially on the microscopic examination that we have relied for our determinations.

Column I. presents the characters of the principal minerals of *ancient* rocks composed of quartz grains, of which some are milky, and a good many are covered with hydrate of iron. Associated with the quartz are many black particles of hornblende, mica, magnetite, and yellow and

—ante-tertiary, the second (II.) those of *recent* rocks—tertiary and post-tertiary. We only mention those minerals which are found in the deposits.

I.	II.
Quartz—containing many liquid enclosures.	*Quartz*—containing vitreous enclosures.
Orthoclase—without inclusions or rare liquid inclusions, dull aspect, and milky colour, crystals tabular and thick, Carlsbad twins.	*Sanidine*—many vitreous and gaseous inclusions, aspect vitreous and brilliant, structure zonary, characteristic cracks independent of the cleavage; cleavage following $\infty \bar{P} \infty$. Baveno twins.
Microcline.	Wanting.
Plagioclase—in general aspect dull, decomposed in micaceous substance into epidote, in pinitoïde, in fibro-radiate zeolithic matter, in quartz, in calcite.	*Plagioclase*—(Microtine), aspect vitreous, in general decomposition less advanced in the Microtine than in the plagioclases of ancient rocks; vitreous and gaseous enclosures more frequent and better marked; enclosures of associated minerals, &c.
Pyroxene—enstatite, bronzite, diallage and augite, the latter very often decomposed, transformed into ouralite.	*Pyroxene*—especially augite, slightly decomposed; numerous vitreous enclosures, especially in the augites of basalts, zonary.
Amphibole—greenish colour, often decomposed into epidote, &c., associated with quartz and calcite; fibrous forms, extremely irregular (Hypersthene).	*Amphibole*—deep brownish tint, generally with crystallographic contours more marked, zones of different colours, sections surrounded with magnetite, compact, numerous inclusions.
Muscovite.	Wanting or secondary.
Wanting.	*Trydimite.*
Wanting.	*Leucite.*
Wanting.	*Nosean* and *Hauyne.*
	Zeolithes.
Tourmaline.	Wanting.
Anatase, *Rutile*, *Brookite.*	Wanting.
Cordierite.	Extremely rare.

It is scarcely necessary to mention that all the foregoing refers only to massive crystalline rocks, and when the minerals are in an isolated state we cannot always say whether they come directly from these rocks, or from the disintegration of sedimentary layers, or from schisto-crystalline rocks. These latter frequently occur in the deposits. In these questions we have always taken into consideration the lithological associations and the geographical position of the deposit. J. M. and A. R.

greenish coloured glauconitic casts of Foraminifera. Most of the quartz particles are seen to be of clastic origin. Sections of a pale green mineral of a lamellar structure are biotite. Some sections have the characteristic cleavage of hornblende; kaolinised feldspar is rare.

Some of the larger mineral particles making up the annelid tubes are about 6 mm. in diameter, these are pieces of quartz, and little pebbles, which last, by transmitted light, are seen to be pieces of Cambrian (?) sandstone, composed of angular quartz, triclinic feldspar, and mica. Others of these fragments are diabase, composed of augite, triclinic feldspar, and quartz, others are tourmaline rock, of which the base is quartz; and finally, other pebbles are fragments of gneiss and amphibolic gneiss.

In the mud in the sounding-tube there was a rolled fragment of gneiss 2 centimetres in diameter.

List of the Animals taken at this Station.

Pisces.	
Cottunculus microps.	Collett.
Liparis liparis.	L.
Lycodes muræna.	Collett.
,, *pallidus.*	,,
Motella macrophthalma.	Stur.
Mollusca.	
Arca pectunculoïdes, var. (*septentrionalis*).	Sc.
Buccinum mörchi.	Friele.
,, *hydrophanum*, var.	Hancock.
Fusus turritus.	M. Sars.
,, *lachesis.*	Mörch.
,, *sabini.*	Gray.
Mohnia alba.	Fr.
Echinoidea.	
Pourtalesia jeffreysii.	Wyv. Thom.
Ophiuroidea.	
Ophioglypha signata.	Vll.
Asteroidea.	
Archaster tenuispinus.	Düb. & Kor.
Crustacea.	
Bythocaris payeri.	Heller.
Hymenodora glacialis.	Bucholz.
Diastylis josephinæ.	G. O. Sars.
,, *longipes.*	G. O. Sars.
Cyclaspis longicaudata.	G. O. Sars.
Boreomysis insignis.	G. O. Sars.
Eurycope gigantea.	G. O. Sars.
,, *corunta.*	G. O Sars
Anonyx lagena.	Kröyer.

Atylus carinatus.	Fabr.
Eusirus cuspidatus.	Kröyer
Halirages elegans.	n. sp.
Haploops setosa.	Bœck.
Ægina spinosissima.	Stimpson.
Scalpellum nymphocola.	n. sp.
Pycnogonida.	
Nymphon strœmii.	Kröyer.
,, *grossipes.*	Fabricius.
,, *macronyx.*	G. O. Sars.
Colossendeis proboscidea.	Sabine.
Annelida.	
Eunoe equitis.	n. sp.
Nephthys longisetosa.	Œrst.
Nothria hyperborea.	Hansen.
Trophonia.	n. sp.
Thelepus circinatus.	Fabr.
Sabella (fragt.).	
Nemertes.	n. sp.
Phascolosoma.	
Tomopteris onisciformis.	
Medusæ.	
**Lucernaria bathyphila*, n. sp.	Haeckel.
Porifera.	
Stylorhiza stipitata.	Osc. Schmidt.
Polyzoa.	
Alcyonidium.	
Alcyonaria.	
Alcyonium.	

(*d.*) *Soundings, Dredgings, and Trawlings on the Ridge.*

Sounding 7. Lat. 59° 58′ N., long. 7° 22′ W. 27th July 1880. Depth, 300 fathoms. Surface temperature, 55·0°; bottom temperature, 48·0°.

Blue Mud, plastic, earthy, with many gritty particles.

Carbonate of calcium 11·77 per cent., consists of a few Coccoliths and Coccospheres, Globigerinas, Orbulinas, Pulvinulinas, Truncatulinas, Uvigerinas, Miliolas, &c., fragments of Echini, Ostracodes, Molluscs.

Residue 88·23 per cent., blue-brown, consists of—

Minerals [70·00], m. di. ·25 mm., with many much larger particles, many rounded; quartz, mica, augite, hornblende, magnetite, chert, mono- and triclinic feldspar, fragments of sandstone, mica-schists, and other rocks, glauconite, and many fragments of highly altered rocks resembling glauconite.

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* This species is described in Haeckel's "*System der Medusen*," p. 640.

Siliceous organisms [1·00]: one or two Radiolarians and fragments of other siliceous organisms, and a few glauconitic casts.

Fine washings [17·23]; fine mineral particles with argillaceous matter.

Remarks.—The carbonate of lime consists chiefly of the remains of surface organisms.

The feldspar is generally kaolinised; typical glauconite is found in grains more or less mammillated and furrowed; some are quite green, while others are reddish coloured. Among the larger fragments are pieces of feldspathic sandstone (6 mm. in diameter) of granite and fine-grained mica schist.

Sounding 17. Station 2. Lat 60° 29′ N., long. 8° 19′ E. 28th July. Depth, 375 fathoms. Surface temperature, 53·0°; bottom temperature, 31·0°.

A small quantity of mud came up in the sounding tube, of which the following is a description:—

BLUE MUD, plastic, coherent, with many rather large gritty particles—streak lustrous.

CARBONATE OF CALCIUM 14·20 per cent., consists of a few Coccoliths, Globigerinas, a few Miliolinas, Rotalias, Nonioninas, Truncatulinas, Ostracode valves, and fragments of Echini.

RESIDUE 85·80 per cent., brownish, consists of—

Minerals [70·00], m. di. 25 mm., with many particles over 1 mm. in diameter—quartz, mica, magnetite, feldspar, hornblende, glauconite, augite, fragments of ancient and recent volcanic rocks.

Siliceous organisms [2·00]: one or two Sponge spicules, glauconitic casts of Foraminifera, few Diatoms.

Fine washings [13·80]; fine mineral particles with argillaceous matter, and a very few fragments of siliceous organisms.

Remarks.—The dredge, with two swabs and a bread bag in the netting, was put over at 8 P.M. on the 28th, and hauled in at 4 A.M. on 29th July.

It contained over a quart of gravel and small stones, and some larger stones—some of them were covered with a thin coating of peroxide of manganese on one of their surfaces, and had many serpulæ and polyzoa attached.

The following are the principal varieties of rocks dredged :—

1. A fine-grained reddish sandstone (Cambrian?) compact, with lamellæ of mica. This fragment is about 12 × 8 × 4 inches, and had polyzoa, serpulæ, and rhizopods attached to it. The angles are more or less rounded. On the upper surface there are parallel striæ, which may be glacial markings. The whole upper surface and edges are blackened by manganese deposit. This fragment was only very partially imbedded in the mud.

2. A rounded fragment of diorite, fine-grained, containing plagioclase, orthoclase, hornblende, and quartz. This fragment was also blackened by manganese except the under surface, where it evidently rested on the mud, and is about 4 inches in length.

3. A micaceous sandstone, fine-grained; the mica appears to be biotite. This fragment is about 5 inches long and is angular.

4. Mica-schist with biotite.

5. Altered mica-schist.

6. Gneissic rock, with quartz, orthoclase, and mica.

7. Diorite—containing plagioclases, amphibole, and quartz.

8. A fine-grained limestone.

9. Compact crystalline rock, containing hornblende, quartz, and feldspar passing to diorite.

10. Amphibolic rock.

11. Chloritic rock.

The majority of these fragments were covered on one of their surfaces with a black deposit of manganese, and nearly all of them when lying on the bottom most probably projected above the deposit in which they were placed. Some of them were perfectly rolled fragments with smooth surfaces, while others were angular.

List of the animals taken in the dredge.

Mollusca.	
Fusus islandicus (young).	Chemnitz.
,, *lachesis.*	Mörch
Pleurotoma declivis.	Lovén.
Ophiuroidea.	
Ophiactis abyssicola.	Ljn.
Ophioscolex glacialis.	Müll. & Tr
Asteroidea.	
Crossaster papposus (Linck), var. *septentrionalis.*	n. sp.

Porifera.	
Tisiphonia agariciformis.	Wyv. Thom.
Reniera, sp.	
Holtenia (?) (fragment).	
Annelida.	
Serpula, attached to stones.	
Actinia.	
Halcampa clavus.	
Hydroida.	
Tubularia indivisa.	
Hydroid (?).	
Cephalopoda.	
Cephalopod.	
Polyzoa.	
Lepralia (*Alysidota*) *alderi.*	Bk.
,, *granifera.*	Johnst.
,, *polita.*	Norman.
,, *dutertrei.*	Aud.
Alecto (*Stomatopora*) *granulata.*	Hincks.
Diastopora obelia.	
Discoporella hispida.	Hincks.
Pycnogonida.	
Nymphon.	

Sounding 28. Lat. 60° 2′ N., long. 7° 4′ W. 4th August 1880. Depth, 285 fathoms. Surface temperatures, 56·5°. Bottom temperature, 48·0°.

Blue-brown mud, slightly coherent with many gritty and sandy particles.

Carbonate of calcium 16·29 per cent., consists of Coccoliths, Coccospheres, Globigerinas, Orbulinas, Truncatulinas, Miliolinas, Pulvinulinas, Nonioninas, &c, fragments of Echini, Molluscs, Ostracode valves.

Residue 83·71 per cent., brownish, consists of—

Minerals [70·00], m. di. ·25 mm., with fragments over 1 mm. in diameter. Quartz, rounded fragments of sandstone and other rocks, magnetite, hornblende, glauconite, and highly altered fragments of rocks resembling glauconite.

Siliceous organisms [2·00]: a few Diatoms and glauconitic casts.

Fine washings [11·71]; fine mineral particles and argillaceous matter.

Station 1. 27th July. 305 fathoms. Lat. 60° 4′ N., long. 7° 37′ W. Bottom temperature, 47·1°. Surface temperature, 54·8°.

A little bluish mud came up in the sounding tube.

The dredge was used without bag.

It came up with about a pint of rounded and angular stones,—sandstone, gneiss, mica-schist, diorite,—the same as those taken at Station 2.

List of the animals taken.

Mollusca.	
Platydia anomioïdes.	Sc. and Ph.
Astarte sulcata, var. (*minor*).	Da Costa.
Echinoidea.	
Dorocidaris papillata.	A. Ag.
Echinus norvegicus.	Düb & Kor.
Crustacea.	
Munida rugosa.	Fabr.
Annelida.	
Placostegus tridentatus.	Fabr.
Serpula, attached to stones.	
Porifera.	
Sponges, attached to stones.	
Cephalopoda.	
Cephalopod.	
Corals.	
Caryophyllia.	
Polyzoa.	
Lepralia granifera.	

CONCLUDING REMARKS.

The dredgings and trawlings during the "Knight Errant's" cruise have, according to the above lists and the supplementary reports which follow, given us 16 new species and one new genus.

The trawlings and dredgings in the warm area (stations 4, 5, 6, and 7) yielded 71 species. The single trawling in the cold area (station 8) yielded 47 species.

It is a somewhat remarkable fact that in these dredgings there are only 2 species common to both areas, viz., *Haploops setosa* and *Nymphon strœmii* excluding of course the foraminifera.

It will be interesting to learn if the same remarkable difference in the fauna on either side of the Wyville Thomson Ridge will be shown by more extended dredgings and trawlings during the present season in H.M.S. "Triton."

The dredgings on the ridge did not yield many animals, and these resemble rather those of the warm, than of the cold area.

The animals captured at the stations surrounding North Rona all belong to known British species.

What is the legitimate limit of the "British fauna"? Are the Farœ Channel animals to be included in it? These are questions which have been often asked, and, although they appear to us unimportant, yet are not without interest.

When we regarded the marine fauna as having a depth limit, the question answered itself—the British fauna ended doubtless with the existence of the fauna. Now, since we know that the marine fauna has no depth limit, we must, if we wish a limit, fix an artificial one.

Temperature is the most important factor in the distribution of marine species. The mean annual temperature of the ocean and of the shallow water around coast-lines varies from about 29° Fahr. in the polar regions to about 75° Fahr. under the equator. This great inequality of temperature is the limiting cause of the distribution of marine species, both at the surface of the sea and in shallow water.

Pelagic species have a marked and limited distribution depending on temperature,—quite as much as species inhabiting the shore waters,—and this distribution can be traced on the bottom of the ocean in many instances.

By an examination of an oceanic deposit, it is possible to tell approximately its latitude from the character of the dead shells of surface organisms found in it. The depth from which the deposit came, and also its longitude, can in many instances be approximately determined by careful microscopic examination of the fragments, organic and inorganic, of which it is composed. While the surface of the ocean, like the surface of the land, has its climates, it is quite otherwise with the deep sea.

The mean temperature of the bottom of the ocean is about 35° Fahr., so that an enormous expanse of the sea-bottom, covering nearly three-fourths of the surface of the earth, is under circumstances where there is no bar to general diffusion, and the result is that this vast area, with a temperature say under 40° Fahr., admitting of free migration, is inhabited by a fauna whose most marked characteristic is extreme uniformity.

The temperature of 35° Fahr. rises in the polar regions towards the surface, and we should expect therefore that the shore and deep-sea faunas would meet in these regions in comparatively shallow water.

Our deep-sea investigations give many examples which tend to corroborate this view.

In the Faroe Channel we have a mixture of abyssal, arctic, and modified British forms. Further investigations may show that a temperature limit can be drawn within which the British fauna should be restricted, but it is at the same time evident that this fauna is continuous, on the one hand, with the abyssal, and, on the other, with the arctic fauna in the Faroe Channel.

We desire to acknowledge our indebtedness to the many scientific men who have supplied us with information and furnished us with reports.

In the work of the exploration we were throughout assisted by Lieut. Hammond, R.N.

In the practical zoological work we received much assistance from Mr. Frederick Pearcey and Mr. James Chumley, assistants on the staff of the "Challenger" Expedition Commission.

JOHN MURRAY.
THOS. H. TIZARD.

"CHALLENGER" OFFICE, 32 QUEEN STREET,
EDINBURGH, *May* 1882.

Report on the FISHES. By Dr. A. Günther, F.R.S.

This Report was received by the late Sir C. Wyville Thomson in November 1880.

The bathybial fish-fauna which surrounds the British Islands was hitherto almost unknown. Besides the stray specimens which now and then were found thrown ashore or floating on the surface, no further evidence of the existence of this fauna was obtained, except on two occasions, viz., on a dredging-excursion of Dr. Gwyn Jeffreys in 1867, from a depth of from 80 to 90 fathoms;* and during the cruise of H.M.S. "Porcupine" in 1869, from a depth of from 200 to 500 fathoms.†

Neither of these two contributions can compare as regards interest and number of specimens with the series obtained during the cruise of the "Knight Errant"; and it would seem as if now only the rich spoil, which I ventured to indicate in 1867 as likely to result from an exploration of the deep sea round the British Islands, were being gathered. Six out of the ten species obtained are new to the British fauna, and, of course, represent but a small fraction of the actual number of British deep-sea fishes. Much, therefore, remains to be done. The laws which govern the bathymetrical distribution of fishes are still obscure; and it is evident that a series of continued systematic observations, such as can be made in a limited oceanic district, like that round the British Islands, whose hydrographic conditions, with its surface and coast fauna, are so well known, is most likely to reveal the chain of facts which cannot be recognised in disjointed observations made at distant localities. Besides, there are not a few obscure points in the life history of our food-fishes which may well be expected to be cleared up by the deep-sea dredge; such are the unaccountable disappearance from certain parts of the coast of fishes like the haddock, and the change of habitat of many fishes according to the season, a change which evidently much more frequently takes place in a vertical than in a horizontal direction. It is therefore to be hoped that the present successful expedition will be followed by equally well conducted efforts.

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* See *Ann. and Mag. Nat. Hist.*, 1867, vol. xx. p. 287.

† *Ibid.*, 1874, xiii. p. 138.

The collection submitted to my examination contains a much greater proportion of arctic forms than of southern, and in this respect differs entirely from that made by Mr. Gwyn Jeffreys at a less depth. The only southern form is *Haloporphyrus lepidion* which we knew previously from the Mediterranean, Japan, and South Atlantic. Singularly, again, no trace of a *Trachypterus* or *Regalecus* was obtained; and we can account for their absence only by the supposition that it is difficult to enclose these long snake-like fishes in the dredge, and that young specimens, from their extreme delicacy of structure, are probably torn into fragments and lost long before the net reaches the surface. Some of the species had been previously obtained by the Scandinavian expeditions in similar latitudes towards the east. As all the species will be fully referred to or described in my report on "Challenger" deep sea fishes, only a few notes on them are appended here.

1. *Chimæra monstrosa*, L.—A young specimen was obtained at a

depth of 555 fathoms; therefore, this fish will have to be admitted in the fauna of the deep sea. Its horizontal distribution includes the northern and southern coasts of Europe, Japan, and the Cape of Good Hope.*

2. *Cottus thomsonii*, sp. n.—Hitherto one species only of this littoral genus was known from the deep sea, viz., *Cottus bathybius*, which was dredged on the "Challenger" expedition near Japan in a depth of 565 fathoms. The single specimen before us was obtained in 555 fathoms (Station 4), and is 7 inches long. It may be shortly characterised thus:—

The præopercular spines, like the remainder of the armature of the head, are short pointed tubercles covered by the skin. Four similar spines are placed in a quadrangle on the crown of the head, the quadrangle being much longer than broad. Eyes large, as long as the snout, their longitudinal diameter exceeding the width of the interorbital space. Vomerine teeth in two oblique bands separated in the middle; palatine teeth none. The first dorsal fin enveloped in skin, continuous with the second. Ventrals rather short, terminating at a considerable distance from the vent. Skin with scattered minute granules. Colourless (in spirits). D. $\frac{5}{17}$, A. 13, P. 22, V. 2.

3. *Cottunculus microps*, Collett.—This singularly shaped Cottoid is quite a recent discovery, a single very young specimen having been obtained by the Scandinavian explorers and described by Mr. Collett. Adult examples, up to 12 inches long, in a perfect state of preservation, are in the collection. Station 8, 540 fathoms.

4. *Liparis liparis*, L.—New to the deep-sea fauna. Station 8, 540 fathoms.

5. *Lycodes muræna*, Collett, and 6. *Lycodes pallidus*, Collett—both new to the British fauna, and only recently described. Station 8, 540 fathoms.

7. *Haloporphyrus lepidion*, Risso.—Specimens of this fish, which was originally known from Madeira and the Mediterranean, and met

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* This specimen was 2 feet in length (caudal filament included). When taken from the trawl the pectoral and dorsal fins were covered with a green sheen on a velvety black ground, the sheen being more pronounced at the base of the fins than towards the tips. The back, tail, and head were light brown. The belly and long whip-like portion of the tail were white. There was a bluish colour about the mouth and gills. The eye had a beautiful golden appearance. A green sheen surrounded the pupil. J. M.

with by the "Challenger" in the Japanese Sea and South Atlantic at depths of 345 and 600 fathoms, seem to be quite common in the British district, having been obtained at Station 4 in 555 fathoms, and at Station 6 in 530 fathoms.

8. *Brosmius brosme*, Müll.—A large example in 530 fathoms (11th August 1880); new to the deep-sea fauna.

9. *Motella macrophthalma*, Stur.—Previously known from a depth of 80 fathoms; the specimens obtained on this occasion come from a depth of 540 fathoms; Station 8.

10. *Macrurus*, sp. n. (?).—Two young specimens from Station 4, 555 fathoms, which have lost the greater part of their scales, approach closely *M. trachyrhynchus*, and may possibly represent only the young state of this species. Their snout is conspicuously shorter than in a large specimen of the true *M. trachyrhynchus*, from the Mediterranean, but as this may be due to age, I hesitate to give an opinion, until I have had an opportunity of examining smaller specimens from the Mediterranean. New to the British fauna.

Report on the MOLLUSCA. By Dr. Gwyn Jeffreys, F.R.S.

This Report was received by the late Sir C. Wyville Thomson in November 1880.

Station 1; 305 fathoms.

Platydia anomioïdes, Scacchi and Philippi.
Astarte sulcata, Da Costa; var. *minor*.

Station 2; 375 fathoms.

Fusus islandicus, Chemnitz (young).
F. lachesis, Mörch.
    Tritonium terebrale, M. Sars (MS.); not *F. terebralis*, Gould, which is *F. spitzbergensis* of Reeve.
Pleurotoma declivis, Lovén.

Station 3; 53 fathoms.

Circe minima, Montagu.
Venus fasciata, Da Costa.
Tapes virgineus, Linné (young).
Tellina crassa, Gmelin.
Psammobia costulata, Turton.

- *Mactra solida*, L.; var. *elliptica*.
- *Saxicava rugosa*, L.; var. *arctica*.
- *Eulima polita*, L.
- *Natica montacuti*, (*montagui*) Forbes.
- *Aporrhaïs pes-pelecani*, L.

Sounding; 38 fathoms.

- *Venus fasciata*, Da Costa.

Station 5; 515 fathoms.

- *Fusus sarsi*, Jeffreys; (young).
    - *F. togatus*, Mörch.
    - *F. mœbii*, Dunker and Metzger.

N.B.—*F. ebur* of Mörch was admitted by him to be only a worn specimen of a variety of *F. propinquus*, Alder.

Station 6; 530 fathoms.

- *Amussium hoskynsi*, Forbes.
    - *Pecten imbrifer*, Lov.
    - *P. mammillatus*, M. Sars.
- *Aporrhaïs serresianus*, Michaud.
- *Fusus fenestratus*, Turton.
    - *Buccinum fusiforme*, Broderip.
- *F. berniciensis*, King, var. *elegans*.
    - *F. islandicus*, Lov.; not of Chemnitz.

Station 7; 530 fathoms.

- *Arca pectunculoïdes*, Sc.
    - *A. raridentata*, S. V. Wood.
- *Leda lucida*, Lov.
- *L. frigida*, Torell.
- *Nucula tumidula*, Malm.
    - *N. pumila* (Lov.), Asbjörnsen.
- *N. corbulöides*, Seguenza.
- *Cardium minimum*, Ph.
- *Neæra striata*, Jeffreys.
- *N. obesa*, Lov.
- *Hela tenella*, Jeffreys; young.
- *Natica montacuti*, Forbes; young.
- *Aporrhaïs serresianus*, Michaud; young.

Cerithium metula, Lov.
Columbella costulata, Cantraine.
C. haliæeti, Jeffreys.
Back. Synonym.
Cylichna alba, Brown.
C. ovata, Jeffreys.

Station 8; 540 fathoms.

Arca pectunculoïdes, Sc.; var. *septentrionalis.*
Buccinum hydrophanum, Hancock; var.
B. mörchi, Friele.
Fusus turritus, M. Sars.
    Not *F. propinquus*, Alder; var.
F. lachesis, Mörch.
F. sabini, Gray.
        F. stimpsoni, Mörch.
Mohnia alba, Friele.

I subjoin a list of what I consider the northern species of *Buccinum*. For their synonyms see the "Annals and Magazine of Natural History for December 1880":—

1. *Buccinum glaciale*, Linné.
2. *B. undatum*, L.
3. *B. grœnlandicum*, Chemnitz.

This is closely allied to *B. undatum;* and both may be one and the same species.

4. *B. hydrophanum*, Hancock.
5. *B. humphreysianum*, Bennett.

Not *B. humphreysianum* of Möller, Lovén, Middendorff, M. Sars, Danielssen, or Malm.

6. *B. totteni*, Stimpson.
7. *B. tenue*, Gray.
8. *B. ciliatum*, Fabricius.

Report on the CRUSTACEA. By the Rev. A. M. Norman, Burnmoor Rectory, Fence Houses, Co. Durham.

This Report was received by the late Sir C. Wyville Thomson in November 1880.

Mr. Norman says:—"I send a list; it is a very interesting one. No. 8 was a grand haul, the best I have ever examined from the North Atlantic. It leads off with a species (*Bythocaris Payeri*, Heller) discovered by the German Arctic Expedition. The second (*Hymenodora glacialis*, Bucholz) was discovered in the Austrian Arctic Expedition, and there follow several of the species of the Norwegian Expeditions. You will see that there are three or four things which I take to be new; one of these, the *Nephropsis*, is not unlike *Nephrops norvegicus*, but the arms quite different, not angled, and hairy, and the eye rudimentary.

Station 1.

Munida rugosa, Fabr.

Station 3.

Stenorhynchus longirostris, Fabr.
Hyas coarctatus, Leach.
Ebalia tuberosa, Pennant.
Munida rugosa, Fabr.
Ligia oceanica (this must have been from Shore).
Eurydice truncata, Norman.
Scalpellum vulgare, Leach.

Station 4.

Munida tenuimana, G. O. Sars.
Nephropsis atlantica, n. sp.

Station 5.

Dorhynchus thomsoni, Norman.
Amathia carpenteri, Norman.
Munida tenuimana, G. O. Sars
Two or three Amphipods (small) to be examined.

Station 6.

Geryon tridens, Kröyer.
Munida tenuimana, G. O. Sars.

Station 7.

Amathia carpenteri, Norman.
Munida tenuimana, G. O. Sars.
Eurydice polydendrica, Norman and Stebbing (MS.).
Haploops setosa, Boeck.
Ampelisca compacta, n. sp.
One or two more Amphipods to be examined.

Station 8.

Bythocaris payeri, Heller.
Hymenodora glacialis, Bucholz.
Boreomysis insignis, G. O. Sars.
Diastylis Josephinæ, G. O. Sars.
„ *longipes*, G. O. Sars.
Cyclaspis longicaudata, G. O. Sars.
Eurycope gigantea, G. O. Sars.
„ *cornuta*, G. O. Sars.
Anonyx lagena, Kröyer.
Atylus carinatus, Fabricius.
Eusirus cuspidatus, Kröyer.
Halirages elegans, n. sp.
Haploops setosa, Boeck.
Ægina spinosissima, Stimpson.

Nephropsis atlantica, Norman, n. sp.

Carapace finely granulated and pubescent all over, with strongly marked transverse lines; rostrum rather longer than the peduncle of the upper antennæ, its extremity acute, its sides bearing two pairs of strong spines; a third pair of spines is situated at its base, and a fourth pair on the front of the carapace over the insertion of the exterior antennæ. The spines just described are the largest, but there are also on the central portion of the carapace two rows of about six spines each, of which the foremost is the largest, while the others are very small, these rows pass backward from the central portion of the base of the rostrum; there is another and strong spine on a line with and behind the spine which is situated on each side of the base of the rostrum.

Pleon having the segments furnished with a slight central keel dorsally; the epimera of the first segment not produced downwards, those of the four following segments, greatly produced downwards triangularly, and gradually attenuating, end in sharp spine-like points, the anterior margins of the epimera of the second segment furnished with a single acute anteally directed spine; epimera of the sixth segment with two small spine-like points, one directed downwards, the other backwards over the insertion of the outer uropods; telson quadrate, the extremity truncated, bearing two divergent ridges which terminate at the distant corners in spine-like points; uropods gently rounded at their extremities, each with two raised ridges, one central, the other running along the outer margin and terminating in strong spines; there is also a spine on the upper surface of the basal joint.

Eyes minute, and apparently devoid of lenses, of a pink colour, lying close together and touching each other, being situated directly under the rostrum, by which they are entirely concealed, and resting on the upper antennæ.

Upper antennæ, which are furnished with two flagella as in allied genera, have the first and third joint subequal in length, and the middle joint about half their length; the flagella are about half as long again as the peduncle.

Lower antennæ are, in the specimen procured, imperfect, but the peduncle is short, equal in length to that of the upper antennæ; green gland with a conspicuous opening on the under side of the basal joint.

Chelipeds densely setose; with rounded joints, which present no appearance of angularity; the meros, which is the largest joint, does not quite reach the extremity of the rostrum; it bears a single spine at the extremity of the upper and outer margin, and another on the under surface; carpus furnished with three spines on the inner and one on the outer margin, and one on the under surface; hand unarmed, elongate, ovate, finger and thumb acute, with crenated inner margin, their tips crossing when closed.

The two following pairs of feet chelate, their coxæ furnished on the inner margin with large lobes, that of the third pair having a hook-shaped process on the outer side of the extremity of this lobe.

First pair of pleopods elongate, spatulate, porrected between the bases of the pereiopods, adpressed closely to the body, and reaching the coxæ of the third pair.

Length 3½ inches. Length of chelipeds rather more than 2 inches.

"Knight Errant" August 10, 1880. Station 4; in 555 fathoms.

Mr. Wood Mason (*Journal Asiatic Society of Bengal*, vol. xiii. 1873; and *Ann. Nat. Hist.* ser. 4, vol. xii. 1873, p. 59), established the genus *Nephropsis* in 1873 for the reception of a small lobster-like crustacean which he procured in 260–300 fathoms off Ross Island, on the coast of the Andamans. The genus approaches very closely to *Nephrops*, but differs from it in the absence of the antennal scale of the lower antennæ. In 1880 Mr Spence Bate procured a second species, *Nephropsis cornubiensis*, off the Cornish Coast (*Report Brit. Assoc.*, 1880, p. 160), and mentioned that he had in his hands a third species taken during the "Challenger" Expedition in 700 fathoms, south of New Guinea, and a fourth, procured also by the "Challenger" in 800 fathoms off Bermuda, and remarked that "the resemblance of all four species is very close, and the distinction of one from the other is dependent chiefly upon the modified forms of more or less important parts." In the same year Professor A. Milne Edwards described (*Ann. des Sci. Natur.*, vi. 9) *Nephropsis Agassizii* from 1500 meters, coast of Florida, but this description I have not seen; and almost at the same time Mr. S. I. Smith characterised (*Proc. National Museum, Washington*, vol. iii. p. 431) yet another form, *Nephropsis aculeatus*, which was taken off the coast of the United States in 100–126 fathoms. The foregoing description of *N. atlantica* was drawn up in November 1880, and the "Knight Errant" specimen was at the same time returned to Sir Wyville Thomson, and I have not since seen it. Comparing the description with that subsequently published by Mr. Smith, there is the strongest suspicion that they are the same species; but all the forms seem to be very closely allied, if indeed distinct. Mr. Smith describes the carapace of *N. aculeatus* as "showing no difference whatever" from *N. stewartii* except in having rather a longer rostrum. Now the spiny armature of *N. atlantica* is certainly different from that assigned to *N. stewartii*, and therefore I do not feel justified in assigning the "Knight Errant" specimen to *N. aculeatus*, though at the same time I very unwillingly give it a name.

Boreomysis nobilis, G. O. Sars.

Boreomysis nobilis, G. O. Sars, "Crustacea et Pycnogonida Nova in itinere 2do et 3tio Expeditionis Norvegicæ anno 1877 et 1878 collecta," *Archiv. for Mathematik og Naturvidenskab*, 1880, p. 428.

Animal more or less mottled and suffused with red, younger specimens are paler in colour, but apparently the telson is always red. Rostrum horizontal, very acute, nearly as long as the eye when porrected. Antero-lateral corner of carapace produced into a triangular process projecting over the base of the inferior antennæ; hinder margin of carapace excavated in the centre, and there exposing the last segment of the pereion. Eyes rather flattened, broad, reaching slightly beyond the side of the carapace, having a small tubercle on the inner side of the peduncle and just below the well-developed dark-coloured eye itself. Upper antennæ having the second joint of the peduncle short, not half the length of the third, and not so patelliform as is usual in this genus. The lower antennæ have the scale much elongated, narrow, and gradually tapering, twice the length of the peduncle of the upper antennæ, its outer margin plain with a small spine at the apex; the apex slopes at once towards the inner margin and together with that margin is setose. Telson long, but not quite reaching the end of the inner uropods, which show no trace of an acoustic organ, and much shorter than the outer, excavated above, and cleft to about one-fifth of its length, its sides unarmed for half their length, but their distal half set with numerous (about 30) slender, closely-arranged, subequal spines, the cleft portion of the telson closely denticulated. Length about 65 millemetres.

Several specimens taken at Station 8, in 540 fathoms.

The above description was drawn up in 1880, when the specimens came into my hands. On comparison with the description published shortly afterwards by my friend Professor Sars, there can be no doubt of the identity of the "Knight Errant" example with the single male which was dredged by the Norwegian Expedition in 1878 in 459 fathoms, 79° 0′ 59″ N. lat., 5° 40′ E. long. I may add to my original description that the tarsus of the legs is composed of three articulations, as in the type specimen of Sars.

Ampelisca compacta, Norman, n. sp.

Pleon not keeled, a very slight depression across the middle of the fifth segment, hind margin of that segment with a spine-like point, but not largely developed nor upturned. Upper antennæ exceeding the length of the peduncle of the lower by about a length equal to the last joint of that peduncle, flagellum consisting of ten articulations; lower antennæ much longer than the upper, and having the two last joints of the peduncle subequal to each other. Eyes apparently altogether absent. First two pairs of pereiopods with the last joint about equal to the two preceding combined. The last pereiopods have the basos with the posterior lobe well developed reaching to the end of the ischium, the lower margin truncate and slightly concave; ischium equal in length to the two following joints combined, meros short, carpus rather longer, manus not quite equal to the two preceding joints combined, dactylus half the length of manus; the lower joints are all flattened but simple (not produced downwards as in *A. lævigata*). First two pairs of uropods of the same length, subequal in length to the deeply cleft telson, and reaching to about one-fourth the length of the sparingly-ciliated branches of the last uropods; the outer margin of the outer branch of the second uropods bears two spines, and under a high power of the microscope is seen to be minutely crenulated. The entire animal has a rounded compact appearance, and is about 8 millemetres long.

A single specimen. Station 7; 530 fathoms.

Halirages elegans, Norman, n. sp.

Pereion and pleon not carinated, two last segments of the former and two first of the latter bearing a single central dorsal spine-like process, which is small on the first of these segments (and sometimes absent), but increases in size on each of the succeeding segments; fourth segment of pleon with a deep transverse sulcus. Lower and front angles of the head produced into an acute spine-like process; epimera of first and second pereion segments with serrated margins, the first also produced forwards into a sharp angle, rounded behind, the second rounded before and behind. Lower margin of the pleon segments not serrated, bearing rows of rather distant seta-like spines a little within the borders, the second and third segments angled at the hinder corner, and the third also produced into a small spine-formed point, and the posterior margin not waved but finely crenated. Antennæ of both pairs very long, the upper pair as long as the entire animal, peduncles of both pairs remarkably round and smooth, peduncle of the upper pair reaching nearly to the end of the penultimate joint of that of the lower; the first joint large, round, and smooth, with two distal spines on the lower side; the second joint nearly as long as, but only half the thickness of, the first; the third very small. Peduncle of the lower antennæ having the two distal joints subequal in length. All the legs slenderly built, the two gnathopods small and slender, the hand shorter than the wrist, subquadrate, slightly widening from the base to the palm, which is only slightly oblique. Last uropods of great length, more than equal the combined length of the three posterior segments of the pleon, the peduncle not quite reaching to the end of the telson, rounded, smooth, with two distal spines above, branches narrow, round, smooth, margined with spinules, and about twice as long as the peduncle. Telson lanceolate, hollowed above, quite smooth, and not furnished with any spines, apex tridentate, the centre tooth large, the laterals small, the tridentate apex is formed by the telson itself (not by articulated spines).

Length 1 inch. Station 8, 540 fathoms.

This species comes very near to *Halirages quadridentatus*, G. O. Sars,* but differs from his description in the form of the epimera of the first segment of pereion, and in the third segment of pleon. Sars does not describe the telson, which is very characteristic.

Report on the PYCNOGONIDA. By Dr. P. P. C. Hoek.

From Station 3 there is one male *Pycnogonum littorale*, Ström, spec.

From Station 5 two specimens of *Nymphon strœmii*, Kröyer.

From Station 7 two specimens of the same species, and still ten other individuals were dredged at Station 8.

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* "Prodromus descriptionis Crustaceorum et Pycnogonidarum, quæ in expeditione Norvegica, anno 1876, observavit G. O. Sars," *Archiv. for Mathematik og Naturvidenskab*, 1876, p. 357.

The species, an extremely large quantity of which was obtained at Station 8, is the *Nymphon robustum*, Bell, the very same, of which Professor Wyville Thomson published a highly characteristic drawing in his *Depths of the Sea*, under the name of *N. abyssorum*, A. M. Norman.

I got large quantities of the same species from different dredging stations in the Barents Sea; in general the specimens from this locality are larger and stouter than those from the "Knight Errant." The same remark may be made with regard to the specimens of N. *strœmii*, dredged during the cruise of the "Knight Errant," Station 8, and those obtained by the Dutch schooner "Willem Barents" in higher northern latitudes. From the same station (8) a single specimen of *N. grossipes*, Oth. Fabr., and numerous *N. macronyx*, Prof. G. O. Sars, were obtained. The last named species is a very interesting one, which, till now, I knew only from the description of Prof. G. O. Sars. More than forty specimens I picked out from the three bottles with *N. robustum.*

As far as I know the cirriped on the *N. robustum* is new to science. It is a Scalpellum species, for which I propose the name, *Scalpellum nymphocola.**

As for the large Pycnogonid, four specimens of which were dredged also at station 8, it is *Collossendeis proboscidea*, Sabine, spec., a species by no means rare in the cold area of higher northern latitudes. I will include these species in my Pycnogonid memoir; of *N. robustum*, Bell, *N. strœmii*, Kröyer, and *Collossendeis proboscidea*, Sabine, I prepared detailed descriptions for the narrative of the "W. Barents" cruise; so I will give only their names and a very short notice in my "Challenger" publication. (See Hoek Report Pycn. "Chall.," p. 94–99.)

Report on the POLYZOA. By Dr. Geo. Busk, F.R.S.

Station 1; 305 fathoms. A few fragments of rock, on which were minute colonies of

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* A description of this species, with the necessary figures, will be given in my report on the Cirripedia of the Expedition of H.M.S. "Challenger."

1. *Lepralia granifera*, B. M. Cat.
   ? *Microporella impressa*, Audouin; Hincks, in a highly calcified condition.

Station 2; 375 fathoms. Numerous pebbles and fragments of rock:—

1. *Lepralia* (*Alysidota*) *alderi*, Bk.
2. „ *granifera*, B. M. Cat.
3. „ *polita*, Norman.
4. „ *dutertrei*, Aud.
   Lep. woodiana, Bk.
   Lep. dutertrei, Hincks.
5. *Alecto granulata*, B. M. Cat.
   Stomatopora granulata, Hincks.

? 6. *Diastopora obelia.*

? 7. *Discoporella hispida*, B. M. Cat.
   Lichenopora hispida, Hincks.

Both the latter very small and much worn, so as to be scarcely recognisable.

Station 3; 53 fathoms.

1. *Cellepora ramulosa*, Linn.
2. *Cellepora avicularis*, Hincks.
3. *Eschara compressa*, Sowerb. (sp.).
   Cellepora cervicornis, Fleming; Couch; Busk; Sars; Alder; &c.
   Eschara cervicornis, formâ.
   Eschara, Smitt; D'orb; Hincks.
   Millepora compressa, Sowerb.
   Porella cervicornis, Gray.
   Porella compressa, Gray; Hincks.
4. *Bugula flabellata*, J. V. T. (sp.)
   Flustra avicularis, Sow.
   Flustra angustiloba, Lamk.
   Avicularia flabellata, J. V. T.
   Bugula flabellata, B. M. Cat.; Hincks, &c.
   Bugula avicularia, formâ, 2. *flabellata*, Smitt.
5. *Bugula plumosa*, Pallas (sp.)
   Bicellaria plumosa, Blain N.
   Bugula plumosa, B. M. Cat.; Alder; Heller; Hincks, &c.

6. *Flustra foliacea*, Linn. (sp.)
    Eschara foliacea, Linn. Ed. 10.
    Flustra foliacea, Linn. Ed. 12; Solander; B. M. Cat.; Auctt.
7. *Retepora beaniana*, King.
    Retepora cellulosa (pars) Anett.
    Retepora beaniana, King; B. M. Cat.; Hincks, &c.
    Retepora cellulosa, formâ.
        beaniana, Smitt.
    Eschara beaniana, Smitt. 1878.
8. *Salicornaria farciminoides.*
    Sal. farciminoides, Solander; B. M. Cat.; Cuvier; Auctt.
    Eschara and *Flustra fistulosa* (pars), Linn.
    Cellaria salicornia, Lamx; Lamarck, &c.
    Cellaria fistulosa, Searles Wood; Hincks; Smitt, &c.
9. *Lepralia unicornis* var. *ansata*, B. M. Cat.; Auctt.
    Schizoporella unicornis, Hincks.
10. *Porella levis*, Fleming (sp.)
    Cellepora levis, Fleming.
    Eschara teres, Bk.
    Eschara levis, Sars.
    Porella levis (*Eschara* formâ), Smitt; Hincks.

The 17 species above enumerated include 13 Cheilostomata and 3 or 4 Cyclostomata. The latter are remarkable for their small size and strongly calcified condition; as were also some of the Lepralioid forms.

All are well-known northern forms, and none present any peculiarities worthy of remark, except that the two species of *Bugula* are represented by very luxuriant specimens. The condition also under which the specimens of *Porella levis* occurred was rather curious; the two or three fragments were, so to speak, enclosed in, and at first sight continuous with, the ramifications of *Cellepora ramulosa*, and were of the same diameter, so that at the first glance the growth appeared to be formed of two distinct kinds of cells.

All the species, it may be remarked, range as far south as the Mediterranean.

Report on the ANNELIDA. By Dr. M'Intosh, F.R.S.

This Report was received by the late Sir C. Wyville Thomson in November 1880.

Station 1.

Placostegus tridentatus, J. C. Fabr.

Station 3.

Lagisca propinqua, Mgn.
Evarne, n. sp.
Glycera capitata, Œrsted.
Onuphis bilineata, Baird.
Lumbriconereis fragilis, O. F. M.
Ditrypa arietina, O. F. M.
Serpula vermicularis, L.

Station 4.

Empty chitinous tube, probably the same as one filled with ova (molluscan ?) from Canada.

Station 5.

Evarne johnstoni, M'I.
Several Nemerteans (*Enopla* and *Anopla*).

Station 6.

Small *Nothria*, and empty muddy tubes probably pertaining to the Ampharetidæ.

Station 7.

Aphrodita aculeata, L.
Lætmonice filicornis, Kbg.
Leanira hystricis, Ehlers.
Maldane near *sarsi*, Mgn.
Ampharete arctica, Mgn.
Hydroides norvegica, Gunn.
Protula, fragt.

Station 8.

Eunoe equitis, n. sp.
Nephthys longisetosa, Œrst.
Nothria hyperborea, Hansen.
Trophonia, n. sp.
Thelepus circinatus, Fabr.

Sabella, fragt.
Nemertes, n. sp.
Phascolosoma.

Station 10. ?
Tomopteris onisciformis.

Report on the HOLOTHURIOIDEA. By Dr. Hjalmar Théel.

This Report was received by the late Sir C. Wyville Thomson in November 1880.

Lætmogone violacea, Théel (*Preliminary Report on the Holothuridæ of H.M.S.* "*Challenger*," vol. i.; *Bihang Till K. Sv. Vet. Akad. Handl*, Bd. 5, No. 19, Stockholm, 1879, p. 11).

Station 4, 555 fathoms.	Several hundred specimens.
Station 5, 515 fathoms.	One specimen.
Station 6, 630 fathoms.	One specimen.

It is a somewhat surprising and highly interesting fact that this beautiful animal should be found in abundance in a locality so far from Australia (Station 164, lat. 34° 8′ S., long. 152° 0′ E.) where the two specimens hitherto known were dredged up during the "Challenger" expedition, at a depth of 950 fathoms. Moreover, it is impossible to discover any characteristic by which these almost antipodal specimens may be distinguished one from the other.

Some species of Elasipoda vary a good deal in the number and size of the processes and pedicels; in *Lætmogone violacea* as well as in *Oneirophanta mutabilis*, Théel, and *Lætmogone wyville thomsoni*, Théel, this variation is so great that scarcely any one individual resembles another completely. Many forms of Elasipoda appear to congregate in very great numbers on the deep-sea bottoms, walking together in large flocks. During the "Challenger" expedition it was not uncommon to procure at the same time and in the same locality a great many individuals of the same species, sometimes a hundred or more; and this very summer Mr. Murray has found several hundred individuals of *Lætmogone violacea* living together in the same place.

The Elasipoda are essentially deep-sea forms. With few exceptions all hitherto discovered genera and species of this order belong to the oceanic abysses.* Only *Elpidia glacialis*, Théel, has as yet been observed living at comparatively small and moderate depths, about 40 to 100 fathoms, in the Sea of Kara, but the same species was also obtained not far from Greenland, during a Swedish expedition, at a depth of 950 fathoms. The Norwegian Arctic dredging expedition also procured from great depths many specimens larger than those from the Sea of Kara; and the "Challenger" expedition brought home an individual, dredged at Station 160, lat. 42° 42′ S., long. 134° 10′ E., south of Australia, in a depth of 2600 fathoms. From this it is manifest that while *Elpidia glacialis* is able to exist at a great variety of depths, it is really a deep sea form.

Only two forms (*Ilyodæmon maculatus*, Théel, and *Orphnurgus asper*, Théel) are known to live at a depth less than 500 fathoms, and a few from 500 to 1000 fathoms; the remainder, about thirty species, are found at depths ranging from 1000 to 2900 fathoms. The order Elasipoda seems to be represented in all oceans, and the largest, most peculiar, and most characteristic forms prefer the greatest depths. The number of deep-sea dredgings being small in comparison with the large area of ocean, it is as yet almost impossible to arrive at any exact idea of the distribution of genera and species. As a matter of fact, however, the genus *Elpidia*, for instance, has a very wide distribution, its species having been observed at almost all parts of the sea, from the Arctic Ocean to lat. 60° 52′ S., long. 80° 20′ E. south of Kerguelen Islands, and not very far from the antarctic circle, as well as in more scattered localities around the world. As to the distribution of species it has already been mentioned that *Elpidia glacialis* and *Lætmogone violacea* appear to be very widely distributed, and *Oneirophanta mutabilis* has also been procured by the "Challenger" expedition at seven different stations around the world, but not in the Atlantic Ocean.

Echinocucumis typica, Sars (*Ofversigt af Norges Echinodermer* Christiania, 1861, pp. 102–108, pl. x. figs. 11–20, pl. xi. figs. 1–17), Station 7, 530 fathoms. Four specimens.

Thyone raphanus, Düb. and Koren (*Ofversigt af Skandinaviens Echinodermer*; *Kongl. Sv. V. Akad. Handl.*, 1877, pp. 311–312, pl. xi. fig. 58–59, pl. v. figs. 49–55).

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* As far as our present knowledge goes, no Elasipoda are found living at depths less than 40 fathoms.

Station 6, 530 fathoms. One specimen.

Station 7, 530 fathoms. Nine specimens.

All these individuals differ from the typical form described by Düben and Koren in their small size, the largest being only about 15 mm. in length, and 10 mm. in breadth, and some other unimportant differences also exist. The pedicels being scattered over the whole body, seem to be more numerous along the three ventral ambulacra, forming there, more or less conspicuous rows. Pedicels with a few small arcuate spicula, and a small irregular terminal plate. Tentacles with larger and smaller, straight or arcuate spicula, the ends of which are enlarged and perforated. Anus with fine, small, elongated, perforated plates resembling teeth.

Stichopus (?) *tizardi*, nov.

Station 6, 530 fathoms. Two rather incomplete specimens, and some fragments.

Station 4, 555 fathoms. Some fragments.

In consequence of the fragmentary condition of the specimens which have been at our disposal, it has been quite impossible to obtain an exact idea of their form, or to fix the genus to which they belong. The viscera having been ejected it could not be ascertained whether respiratory organs were present or not. The bottle in which the specimens were stored contained also the posterior part of an intestine with two respiratory trees, and it seems probable that these organs belong to the larger specimen. As they bear some resemblance to *Stichopus* I propose, for the present at least, to refer them to that genus.

Body elongated, the length of the larger specimen being about 130 mm. Bivium with some small retractile processes arranged in a row around its foremost part, and with a few larger ones scattered on the back. Trivium with small retractile pedicels. It is impossible to state how the processes and pedicels are arranged on the larger specimen, but the fragments plainly show that the bivium is provided with tubercles or processes all round the body, and that the pedicels are disposed in rows on the bivium. Mouth anterior ventral; anus posterior, terminal, subdorsal. Tentacles twenty of almost equal size, their terminal part rather large, with some retractile processes. Integument very thick and soft, with two kinds of calcareous deposits; small G-shaped spicula; and other bodies representing the form of a cross or star, composed of four long, straight arms with the ends more or less enlarged, flattened and pierced with one large and a few small holes; sometimes the enlarged ends of the arms are connected with one another, forming a more or less round, perforated plate; the centre of the cross always with a large and straight tower or steeple, directed outwards from the body of the animal, and composed of four long, straight, parallel columns, held together by three to seven transverse bands. The pedicels and processes with numerous rather large, more or less arcuate spinous spicula, and the former with a rudimental perforated terminal plate.

Only one pyriform sac, rather slender and cylindrical, the length being about 35 mm. The madreporic canal dorsal, very small, with numerous small spicula, curved in the form of a C, and resembling those of the integument. Each of the powerful longitudinal muscles is double. Genital tubes dichotomously branched, arranged in two rather large clusters, one on each side of the dorsal mesenterium, each cluster being again divided into from five to seven smaller ones. The respiratory trees (if they really belong to these animals) are two, undivided, almost of equal size, about 45 mm. in length, and bearing along their whole length a great many small processes or branches. Colour in alcohol light grey; terminal parts of the tentacles yellowish with some dark points.

Report on Echinoidea. By Professor Alex. Agassiz.

I have examined the things and send you a list. There is nothing new, but I am very glad to have good specimens of *Phormosoma uranus* and *placenta*, which I had not seen, as well as good young specimens of *Echinocardium pennatifidum*, which are interesting.

Dorocidaris papillata, A. Ag.	St. 1	305 fms.
Porocidaris purpurata, W. Th.	St. 7	530 ,,
Phormosoma uranus, W. Th.	St. 4	555 ,,
,, *placenta*, W. Th.	St. 4	555 ,,
	and St. 2	530 ,,
Echinus norvegicus, D. & K.	St. 7	530 ,,
	St. 1	305 ,,
	St. 3	53 ,,
,, *acutus*, Lamk.	St. 3	53 ,,
,, *melo*, Lamk.	St. 3	53 ,,
Echinocyamus pusillus, Gray	St. 3	53 ,,

Pourtalesia jeffreysii, W. Th.	St. 8	540 fms.
Spatangus purpurens, Luke	St. 3	53 „
young (?)	St. 6	530 „
(broken, possibly not the young)		
Echinocardium flavescens, A. Ag.	St. 3	53 „
„ *pennatifidum*, Norm.	St. 3	53 „
with young specimens of the species.		

ASTEROIDEA dredged during the Cruise of the "Knight Errant" in July and August 1880. By W. Percy Sladen, F.L.S., F.G.S.

The collection that forms the subject of the present report, although small numerically, is interesting in many respects. As might naturally be expected, the general facies of the whole is decidedly northern; and with the exception of two of the forms all have been previously recognised under similar conditions of habitat and association. Owing to the limited number of stations and the small number of starfishes obtained at each, I do not in the present instance feel justified in drawing from the study of this group of animals alone any definite generalisations upon the physical and faunatic conditions of the area surveyed. Of the five stations herein concerned, one is situated in the shallow water within the hundred fathom line, and all the forms there dredged are characteristic boreal and North British species; two stations occur in the "cold" area near to stations previously dredged by the "Porcupine,"—one being probably close to the most western extension of the area. The remaining two stations are in the "warm" area and near to the ridge that separates it from the cold area. One of the warm-area stations has furnished a very remarkable starfish, which constitutes the type of a new genus,—altogether distinct from any of its northern congeners; whilst from the second of these stations a recognised boreal species was dredged, which has not previously been found out of the cold area.

With the exception of the new form, each of the species enumerated has been previously taken in the cold area. Upon this fact, however, too much importance should not be placed. As our knowledge of the distribution and adaptability of starfish life increases, there seems much danger of confusing cold-area forms (previously so called) with frigid abyssal forms of far distant localities, which certainly cannot be regarded as belonging to the same geographical or isothermal area. It is not improbable that, when the Asteroidea of the "Porcupine" and "Lightning" cruises have all been critically examined and the results tabulated, in connection with the additional information furnished by the "Challenger" and other expeditions, that some modifications may be necessary in the asterid fauna-lists of the respective areas. Every series of specimens therefore is of especial interest and adds further weight and importance to previous observations.

My hearty thanks are due to Mr. John Murray for the opportunity of examining this collection, as well as for much information.

I. *List of the Species obtained.*

1. *Archaster tenuispinus* (Düben and Koren), Sars.

Station 8. August 17, 1880. Lat. 60° 3′ N., long. 5° 51′ W. Depth, 540 fathoms; bottom temperature, 29°·2 Fahr.; surface temperature, 56°·5 Fahr.; ooze. Three examples.

All fully grown individuals, $R < 5r$; in the largest, $R = 73$ millim., $r = 16{\cdot}5$ millim. These specimens present many of the characters of *A. echinulatus*, Perrier, which is perhaps only a locational variety of the northern species,—at any rate a representative form.

2. *Archaster bifrons*, Wyville Thomson. (*Archaster bifrons*, Wyv. Thom. (1873), *The Depths of the Sea*, p. 122, figs. 17 and 74).

Station 7. Aug. 12, 1880. Lat. 59° 37′ N., long. 7° 19′ W. Depth, 530 fathoms. Three examples.

This elegant and well marked form was named by Sir Wyville Thomson in his account of the "Porcupine" cruise in *The Depths of the Sea;* and two admirable woodcuts are there given, unaccompanied, however, by any description. As no diagnosis of this species has yet been published, the following summary of details will not be out of place:—

Archaster bifrons.—Radii five, elongate, moderately broad at the base, tapering continuously to a finely pointed extremity. Interbrachial angles widely rounded. Minor radial proportion 23·3 per cent., $R = 90$ millim., $r = 21$ millim. $R > 4\frac{1}{4}r$. Radii 25 millim. broad at the base.

Paxillæ of the dorsal area minute, crowded, bearing 20 to 25 spinelets,—5 or 6 in the midst of each crown more robust than the rest.

Marginal plates large and conspicuous. Supero-marginal series about as broad as high, 33 in number from the interbrachial angle to the extremity, covered with granules which become subconical in form on the lateral half of the plate. Each supero-marginal plate bears a single, moderately long, conical, pointed spinelet standing on the rounded angle of the plate and directed outward almost horizontally. Sometimes this spinelet may be reduplified on two or three plates near the middle of the ray. Infero-marginal plates correspondent with the superior series and similar in every respect, covered with similar sub-conical granules, and each with a similar and equal sized spinelet directed horizontally. The supero-marginal spines diminish in size towards the interbrachial angle and towards the extremity; and also the infero-marginal spines, but in a less degree. The largest spines are consequently about midway on the ray. Adambulacral plates form a straight or very faintly festooned margin to the furrow. Ambulacral spines rather elongate, 10 in a lineal series on the furrow-margin of the plate, slightly compressed, not tapering, extremities rounded, the middle spines largest; the others diminishing by gradation to either end of the series, the outermost spine being small and setiform. External to this inner row stands a single large, conical, sharply pointed spinelet, nearly as large and robust as the marginal spines. A few minute setiform spinelets stand at the base on the outer portion of the plate.

Interbrachial areas large. The ventral plates are small, numerous, regularly quadrate, and are divided into lineal series or columns by furrows which extend from the adambulacral plates to the marginal plates,—the breadth of the columns at their inner extremity corresponding with that of the adambulacral plates, but contracting as they proceed outward, in consequence of the diminution of the size of the plates. The ventral plates are covered with papilliform granules or spinelets, and each of those in the angle bears a single, moderately robust, conical pointed spinelet springing from the midst.

Anus distinct. Madreporiform body obscure, hidden by paxillæ; probably situated in the midst of a circular area of more widely spaced paxillæ which occurs in one of the interradia, rather nearer the margin than midway.

Terminal (ocular) plate very minute. Sucker-feet pointed. No sucker disk.

3. *Astropecten andromeda,* Müller and Troschel. (*Astropecten christi,* Düben and Koren,[*] *Öfvers. K. Vet.-Akad. Förhandl.*, 1844, p. 113).

Station 7. Aug. 12, 1880. Lat. 59° 37′ N., long. 7° 19′ W. Depth, 530 fathoms. A single example.

Müller and Troschel[†] described their species as sometimes furnished with small single spinelets on the supero-marginal plates; but no trace whatever of such are to be found in the specimen under notice. In this respect I can confirm the observations of Sars,[‡] and Danielssen and Koren,[§] and also the description given by Düben and Koren.[||] In the "Knight Errant" specimen all the spinulous or papilliform appendages of the actinal surface are invested with a thick membranous tissue which is often more or less united at their bases, and in some parts coalescent even at their extremities, which are joined by web-like and fibrillar extensions. The appearance thus produced is accurately enough expressed by Düben and Koren's "gelatinöst öfverdrag,"[¶] and I have no doubt whatever as to the correctness of their description in this respect; although the character referred to has subsequently been called in question. Sars[**] states definitely that it did not occur in any of his specimens, and he considered that Düben and Koren had been deceived by the presence of foreign matter. Düben and Koren state that the character is not a constant one.

Remarks.—Astropecten andromeda has not previously been dredged out of the "cold" area. The present seems to be an instance of its occurrence within the limits of the "warm" area. It seems probable from this and other sources of information that some modifications will ultimately be required when drawing up a revision of the characteristic fauna-lists of the two areas.

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[*] The date of the first publication of Düben and Koren's name was incorrectly cited by Dujardin and Hupé (*Hist. Nat. Zooph. Échinodermes*, p. 420) as 1834,—a mistake which has subsequently been copied, and has led to an erroneous priority being accorded to Düben and Koren's name. In 1846 Düben and Koren themselves acknowledged Müller and Troschel's claim.

[†] *System der Asteriden*, 1842, p. 129.

[‡] *Oversigt af Norges Echinodermer*, p. 30.

[§] *Nyt Mag. f. Naturvidensk.*, 1877, bd. xxiii. 3, p. 66.

[||] *Kongl. Vet.-Akad. Handl. för År* 1844 (1846), p. 250.

[¶] *Loc. cit.*, p. 251.

[**] *Loc. cit.*, p. 31.

4. *Luidia sarsii*, Düben and Koren.

Station 3. Aug. 3 and 4, 1880. Lat. 59° 12′ N., long. 5° 57′ W. Depth, 53 fathoms. Seven examples.

5. *Porania pulvillus* (O. F. Müller), Norman.

Station 3. Aug. 3 and 4, 1880. Lat. 59° 12′ N., long. 5° 57′, W. Depth, 53 fathoms. A single example.

6. *Mimaster tizardi*, gen. et sp. nov.

Station 4. Aug. 10, 1880. Lat. 59° 33′ N., long. 7 14′ W. Depth, 555 fathoms; bottom temperature, 45°·4 Fahr.; surface temperature, 57° Fahr.; mud. A single example.

Radii five, marginal contour stellato-pentagonal, interbrachial angles sub-acute, the radii tapering gradually to a fine extremity. The lesser radius is in the proportion of 45 per cent., $R = 120$ millim., $r = 54$ millim.; breadth of a ray at the base, 58 millim. Dorsal profile high and gibbous over the disk. Actinal surface convex.

Dorsal area covered with a great number of uniform small paxillæ, closely and equidistantly placed, presenting no definite order of arrangement. The paxillæ consist of a cylindrical pedicel nearly twice as high as broad, surmounted by a crown of 15 to 20 spinelets about equal in length to the pedicel, except where they have been abraded; and the spinelets radiate apart very slightly, which gives a compact appearance to the paxillæ. Papulæ in groups of 3 to 5 occur between neighbouring paxillæ.

Marginal plates, in ventral and dorsal series, small and subtubercular in appearance, 37 to 38 in each series between the interbrachial angle and the extremity of the ray. Each plate or boss is covered with a great number of small spinelets similar to those of the paxillæ, giving them a round, cushion-like appearance. The inferomarginal plates are the largest, transversely sub-oval in form,—the length increasing towards the interbrachial angle, and bear not less than 100 spinelets. The supero-marginal plates are smaller, usually round, and placed rather more aborally than the companion plate of the lower series, the pairs standing consequently slightly oblique. The ventral plates occupy a great space on the actinal surface, and extend up to the very extremity of the ray. Each plate bears a single paxilla, which is rather more robust than those on the dorsal surface, and carries rather fewer spinelets, which are somewhat longer and more widely expanded. In consequence of the size and arrangement of the ventral plates, the ventral paxillæ are more widely spaced than the dorsal ones, and are disposed in regular lines which run from the adambulacral plate to the margin, the lines or columns being marked off by straight furrows or wrinkles in the membrane. As the paxillæ are equidistantly spaced in each of these transverse rows, equally regular and uniform longitudinal lines are also traceable along the ray. In the arm-angle 9 to 10 paxillæ stand in each transverse series, the same number being maintained until about the outer fifth of the furrow.

Each adambulacral plate stands on the furrow-margin as the terminal plate of one of the transverse series above mentioned; and carries a group of 15–20 spinelets resembling a compressed paxilla, only rather more robust than those on the ventral plates. Two of the spinelets (sometimes three) larger than the rest, slightly flattened and tapering to a point, stand at the margin of the furrow. The succeeding spinelets are less robust, and pass in gradation to the group of outermost spinelets which are about equal in size to those of the ventral paxillæ. The 5 or 6 innermost adambulacral plates have much larger spinelets than the others. About 75 adambulacral plates may be counted along the furrow.

The united mouth-plates form a sharp angle inwardly, and a large elongately ovoid, sub-tubercular swelling is developed on their superficies,—the whole surface being covered with spinelets arranged in somewhat similar series to the ambulacral spinelets, standing perpendicular, 7 to 8 along each side of the mouth angle. The aboral portion of each plate is occupied by a compressed paxilliform group, similar to those on the adambulacral plates

Madreporiform body undistinguishable.

Remarks.—The appearance of this magnificent starfish suggests in a remarkable way the association of the prominent external characters of a *Solaster*, a *Pentagonaster* and an *Asterina*. It is entirely distinct from its northern congeners and in structural formula cannot be referred to any genus at present known. Judging from description alone it perhaps resembles most nearly the genus *Radiaster*, recently established by M. Perrier* from a specimen obtained by the U.S. Coast Survey Steamer "Blake" in the dredgings in the Gulf of Mexico and the Caribbean Sea. That *Mimaster* is clearly distinct, however, from that form will be readily seen on comparing the summary given above with that of M. Perrier.

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* *Bull. Mus. Comp. Zool.*, Harvard, vol ix. no. 1, p. 17.

I have great pleasure in naming this interesting species after Captain Tizard, R.N., under whose command the "Knight Errant" cruise was conducted,—an officer to whom science is much indebted for many services and contributions, amongst the foremost of which may be mentioned the important hydrographic investigations on board H.M.S. "Challenger."

7. *Cribrella oculata* (Linck), Forbes.

Station 3. Aug. 3 and 4, 1880. Lat. 59° 12′ N., long. 5° 57′ W. Depth, 53 fathoms. A single example.

8. *Crossaster papposus* (Linck), Müller and Troschel.

Station 3. Aug. 3 and 4, 1880. Lat. 59° 12′ N., long. 5° 57 W. Depth, 53 fathoms. Two examples.

One large specimen having thirteen rays, $R=122$ millim., $r=45$ millim.; and the other a small one with twelve rays.

9. *Crossaster papposus*, var. *septentrionalis*, n.

Station 2. July 29, 1880. Lat. 60° 29′ N., long. 8° 19′ W. Depth, 375 fathoms; bottom temperature, 31° Fahr.; surface temperature, 53° Fahr.; mud. A single example.

An interesting variety was dredged at Station 2 in 375 fathoms, which on account of its well-marked character I consider desirable to recognise by name,—a course further justified by its constancy over a considerable area of distribution. In proposing this step, however, I wish to state clearly that I do not regard the form as specifically distinct from *Crossaster papposus.* The form is ten rayed, and accords in this and other particulars with a number of examples taken at different stations during the "Porcupine" cruise. The chief characters are persistent throughout the whole series of specimens that I have examined; several, however, are present in an extreme degree in the specimen under notice, of which the following may be taken as a brief description:—

Rays ten, short, broad at the base, and sharply tapering, radial proportions $=R<2r$; $R=35$ millim., $r=18$ millim. Dorsal surface of the disk gibbous, sloping rather quickly at the base of the rays. Paxillæ small, numerous, closely crowded, with 10 to 21 spinelets, which are more or less divergent from the pedicel. 15 to 17 paxillæ may be counted in a median interradial line and about 10 across the base of a ray. Papulæ few, not more than 1 to 3 in a group.

Ambulacral spines: (1) furrow series, six on each plate near the mouth, five on the more outward plates, the aboral spine smallest; (2) transverse series composed of eight spines. The two spines nearest the furrow are placed more aborally than the rest, which gives the line of base of each transverse series an aboral curve at the furrow side. The middle spines are longest, the outermost smallest; all tapering to a fine point, robust at the base; no webbing apparent. Mouth-plates with robust mouth-spines, and a prominent series of 9 to 10 secondary superficial spinelets, larger than the marginal mouth-spines. Interbrachial areas covered with small paxillæ, and rather crowded.

Remarks.—On comparing with the above form a typical *Crossaster papposus* of the same diameter, it will be found that in the latter the rays, which are 11 to 13 in number, are less tapering and relatively longer, the proportion being $R > 2 \cdot 5\ r$. The dorsal area of the disk is very little higher than the rays. The paxillæ are larger, fewer, more widely spaced, and bear a greater number of spinelets, usually about 40, which are arranged much more compactly and give the paxillæ a more rounded appearance,—often resembling that of a well-worn brush, the central spinelets being longest. The papulæ are more numerous, 5 to 10 or more. Ambulacral spinelets three in the inner or furrow series,—a fourth very minute one, placed aborally, being present near the mouth. Transverse combs of five spinelets, those near the furrow series longest; line of base straight; webbing at the base more or less present. All the spinelets are more delicate in character than in the variety. Mouth-plates with delicate spines; secondary mouth-spines not more than two or three. Interbrachial areas quite naked or with only one or two small paxillæ.

This variety conforms in several respects with the admirable description given by Danielssen and Koren* of the form which they refer to the *Solaster affinis* of Brandt. The differences, however, are so marked that I cannot regard them as one and the same form; and in none of the specimens which I have examined either from the "Porcupine" or the "Knight Errant" dredgings can I recognise an identity with the specimens described by the eminent Norwegian naturalists. Judging from the description above cited, it seems to me that our variety occupies an intermediate position between the typical form of *Crossaster papposus* and the *Solaster affinis* of Danielssen and Koren; and thus appears to me to strengthen the opinion elsewhere expressed,* that the latter form is probably a locational variation of the type of *C. papposus.*

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* *Nyt Mag. f. Naturvidensk.*, 1877, bd. xxiii. 3, p. 57.

10. *Asteracanthion rubens* (Linné), Müller and Troschel.

Station 3. August 3 and 4, 1880. Lat. 59° 12′ N., long. 5° 57′ W. Depth, 53 fathoms. Three examples; two of them being small.

The large specimen is remarkable for the elongation and attenuation of the radii, and for the comparative paucity and smallness of the dorsal spinelets. These are minute, conical, and almost hidden in the membrane. The margin of the dorsal area is bounded by a regular and prominent line of spinelets, and the median dorsal line is also more or less regular. The other spinelets are quite irregular in disposition and though moderately numerous are inconspicuous in consequence of their small size. The sides of the rays are deeper and more perpendicular than usual. Lateral spines, 2 or 3 in number, placed obliquely. No spines on the sides between these spines and the true dorsal series, and no spines between the lateral series and the ambulacral spines. Forficiform pedicellariæ very numerous on the ambulacral spines, especially in the inner portion of the furrow, also on the sides of the ray; smaller and less numerous on the dorsal area. Forcipiform pedicellariæ comparatively scanty, a few at the base of the marginal dorsal spines, and a greater number at the base of the lateral spines; a few irregularly distributed over the dorsal area. This specimen in some respects simulates the habit of *A. glaciale* in a striking manner.

11. *Asteracanthion mülleri*, Sars.

Station 3. Aug. 3 and 4, 1880. Lat. 59° 12′ N., long. 5° 57 W. Depth, 53 fathoms. A single example.

II. *Station-Lists.*

The following lists will show at a glance the association of the species at each of the stations.

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* Duncan and Sladen, *A Memoir on the Echinodermata of the Arctic Sea to the West of Greenland*, London, 1881, p. 39.

Station 2. July 29, 1880. Lat. 60° 29′ N., long. 8° 19′ W. Depth, 375 fathoms. Bottom temperature, 31° Fahr.; surface temperature, 53° Fahr.; mud.

Crossaster papposus, var. *septentrionalis.*

Station 3. Aug. 3 and 4, 1880. Lat. 59° 12′ N., long. 5° 57′ W. Depth, 53 fathoms; off the island of North Rona.

Luidia sarsii.	*Crossaster papposus.*
Porania pulvillus.	*Asteracanthion rubens.*
Cribrella oculata.	*Asteracanthion mülleri.*

Station 4. Aug. 10, 1880. Lat. 59° 33′ N., long. 7° 14′ W. Depth, 555 fathoms; bottom temperature, 45°·4 Fahr.; surface temperature, 57° Fahr.; mud.

Mimaster tizardi.

Station 7. Aug. 12, 1880. Lat. 59° 37′ N., long. 7° 19′ W. Depth, 530 fathoms.

Archaster bifrons. *Astropecten andromeda.*

Station 8. Aug. 17, 1880. Lat. 60° 3′ N., long. 5° 51′ W. Depth, 540 fathoms. Bottom temperature, 29°·2 Fahr.; surface temperature, 56°·5 Fahr.; ooze.

Archaster tenuispinus.

Report on OPHIUROIDEA. By Professor Theodore Lyman.

I have examined the "Knight Errant" Ophuiroidea. They are as follows:—

Ophioglypha aurantiaca, Vll.	St. 6	530 fms.
,, *signata*, Vll.	St. 8	540 ,,
Ophiactis abyssicola, Ljn.	St. 2	375 ,,
	St. 7	530 ,,
Ophioconia nigra, Mull. & Tr.	St. 3	53 ,,
Ophiopholis aculeata, Gray	St. 3	53 ,,
Ophiothrix pentaphyllum, Ljn.	St. 3	53 ,,
Ophioscolex glacialis, Mull. & Tr.	St. 2	375 ,,
Ophiacantha tridentata, Ljn.	St. 5	515 ,,

It is curious that they did not get things like *Ophiacantha spinulosa*, and several common species of *Ophioglypha*, and that they did get new things, viz., *Ophioglypha aurantiaca* and *O. signata*. The latter, however, stands pretty near the common *O. affinis*.

Report on the Sponges. By Professor Franz Eilhard Schulze.

Station No. 2, July 29, 1880; 275 fathoms.

(1) Two medium-sized specimens of *Tisiphonia agariciformis,* Wyville Thomson (*Depths of the Sea,* p. 74).

(2) An irregularly triangular flattened disc about 15 square centimetres in area and 2·5 mm. thick, flexible, and of the consistency of leather. One edge is irregularly torn, the two others are rounded off smoothly: the latter evidently represent the free margin in its normal condition. The surface on both sides exhibits a system of round pit-like depressions about 1 mm. broad, between which is left a level reticulate lattice-like network of trabeculæ, which also have a thickness of 1 mm. Large numbers of short siliceous spicules occur, pointed at one end and blunt at the other; they are united into a loose skeleton of tri- or quadri-lateral meshes by an extremely small amount of horny substance, and are all of the same form and size. Thus the sponge under notice is a *Reniera* (in the broad sense of the word). The species was hitherto unknown.

(3) A coarsely woven mass of siliceous spicules made up of long rod-like and abundant smaller quinque- and sex-radiate forms; it was probably derived from a *Holtenia.*

Station No. 3; 53 fathoms.

Tetilla Cranium, Müll.

Station No. 7; 530 fathoms. A packet of long tuft spicules from a Hexactinellid, most probably a *Holtenia.*

Station No. 8; 540 fathoms. Several examples of *Stylorhiza stipitata,* Oscar Schmidt (*Sponges of the Gulf of Mexico,* p. 79), a species identical with *Polymastia stipitata,* Carter (*Annals of Nat. Hist.,* 1876, ser. 4, vol. xviii. p. 393.)

Besides adults, young forms also occur, which exhibit a roundish head.

Report on the Foraminifera. By Henry B. Brady, F.R.S.

This Report was received by the late Sir C. Wyville Thomson, in November 1880.

Sea-bottoms.—Specimens of the sea-bottom from five localities have been examined and the Foraminifera determined. Particulars as to locality, physical conditions and the like, are given in the following summary. The letters A, B, C, D, E correspond to the headings of the columns in the distribution-table, and are otherwise used for reference.

A. "Station 1.—July 27; lat. 60° 4′ N., long. 7° 37′ W.; depth 305 fathoms; bottom temperature, 47·1° Fahr.; surface temperature, 54·8°."

Greyish-brown sandy mud, leaving but little residue after washing, and that chiefly hard silicious sand, with larger dark-coloured fragments. But few Foraminifera, principally of large coarse types such as *Anomalina coronata*, *Truncatulina refulgens*, and *Tr. lobatula* and *Uvigerina pygmæa.*

B. "Station 2.—July 29; lat. 60° 29′ N., long. 8° 19′ W.; depth, 375 fathoms; bottom temperature, 31·0° Fahr.; surface temperature, 53·0°."

Brownish sandy mud, with a good many small fragments of rock of darker colour. Foraminifera by no means abundant—the most conspicuous genera being *Globigerina*, *Polystomella*, *Nonionina*, and *Cassidulina.* One or two specimens of the interesting sessile species *Rupertia stabilis* were found in this gathering. A considerable proportion of the *Globigerinæ* were of the small arctic variety, *Gl. borealis.*

C. "Station 4.—August 10; lat. 59° 33′ N., long. 7° 14′ W.; depth, 555 fathoms; bottom temperature, 45·4° Fahr.; surface temperature, 57·0°."

Grey *Globigerina*-ooze, leaving very little residue after washing. The residue composed almost entirely of the shells of Foraminifera, chiefly of *Globigerina bulloides* and *Gl. inflata.*

D. "Stations 6 and 7.—August 12; lat. 59° 37′ N., long. 7° 19′ W.; depth, 530 fathoms; bottom temperature, 45·9° Fahr.; surface temperature, 56·6°."

Globigerina-ooze very rich in arenaceous types of Rhizopoda, notably *Astrorhiza*, *Rhabdammina*, and *Marsipella*, with occasional examples of *Saccammina* and *Storthosphæra.* Of the hyaline species, *Rotalia orbicularis*, by no means a common form, alone requires notice—the specimens being not only plentiful but unusually fine.

E. "Station 8.—August 17; lat. 60° 3′ N., long. 5° 51′ W.; depth, 540 fathoms; bottom temperature, 29·2° Fahr.; surface temperature, 56·5°."

Muddy sand. Of arenaceous Rhizopoda, *Reophax sabulosa* and *R. scorpiurus* are the most remarkable. The former is a large rare species, only previously known by specimens from one of the "Porcupine" stations. The latter is cosmopolitan, but in this particular dredging is particularly abundant. Of the calcareous types, *Cornuspira* claims attention from the gigantic size of some of the specimens, and *Lagena* from the long list of species found; *Pullenia sphæroides* and *Cassidulina lævigata* are also prominent forms. A large proportion of the *Globigerinæ* are of the small northern thick-shelled variety.

Detailed lists of the Foraminifera from the several localities are furnished in the following table. It will be seen from the temperatures recorded in the foregoing summary that the columns headed A, C, and D represent the Rhizopod-fauna of a warm sea-bottom, B and E of a cold area.

A comparison of the Rhizopod-fauna of the cold sea-bottom, represented by column E, with that of the warmer area typified by C and D, suggests some interesting facts in connection with the distribution of species. The larger arenaceous types pertaining to the family *Astrorhizidæ*, such as *Astrorhiza*, *Saccammina*, *Storthosphæra*, *Rhabdammina*, *Jaculella*, *Marsipella*, and *Hyperammina*, are for the most part conspicuously absent from the colder portion of the channel, and appear to be partially replaced by the weaker forms of *Lituolidæ*. The genus *Bulimina* in its typical condition affects the warm area; whilst in the cold, the starved transition varieties which constitute the sub-genera *Bolivina* and *Virgulina* abound. The genus *Lagena* is represented in the cold region by a list of fifteen species; in the warm by only eight. The little thick-shelled *Globigerina borealis*, so far as we know, is confined to the cold area, and, as has been stated, the gigantic *Cornuspira striolata* is similarly limited in distribution. How far these facts may indicate general laws can only be determined by further investigation, and on the comparison of a larger series of soundings than are at present available.

	A	B	C	D	E
Biloculina ringens (Lamk.)	×			×	
depressa, D'Orb.				×	
comata, Brady				×	
elongata, D'Orb.		×		×	
Planispirina contraria (D'Orb.)					×
Miliolina seminulum (Linn.)	×	×		×	×
trigonula (Lamk.), var.				×	
tricarinata (D'Orb.	×			×	×
celata (Costa)	×		×	×	
Cornuspira striolata, nov.					×
carinata (Costa)				×	
involvens, Reuss				× (?)	× (?)
crassisepta, nov.				×	
Psammosphæra fusca, F. E. Schulze					×
Saccammina sphærica, M. Sars				×	
Astrorhiza arenaria, Norman				×	
Storthosphæra albida, F. E. Schulze				×	
Rhadammina abyssorum, M. Sars	×			×	
discreta, Brady				×	
cornuta, Brady				×	
Jaculella obtusa, nov.				×	
Marsipella elongata, Norman				×	
cylindrica, nov.				×	
Hyperammina elongata, Brady				×	×
ramosa, Brady				×	×
Reophax difflugiformis, Brady			×	×	×
scorpiurus, de Montfort			×		×
adunca, nov.				×	
guttifera, Brady					×
sabulosa, Brady					×
Haplophragmium canariense (D'Orb.)				×	×
subglobosum (M. Sars)					×
scitulum, Brady				×	
simplex, Reuss				×	
tenuimargo, nov.				×	
Placopsilina vesicularis, Brady					×
Trochammina squamata, P. &. J.					×
charoides, J. & P.				×	
Webbina clavata, J. & P.				×	
Cyclammina cancellata, Brady				×	
Thurammina papillata, Brady					×
Textularia sagittula, Defrance	×				
trochus (D'Orb.)					×
aspera, nov.				×	
Verneuilina pygmæa (Egger)				×	
Gaudryina pupoides, D'Orb.			×	×	
Valvulina fusca (Will.)				×	
Bulimina marginata, D'Orb.			×	×	
pyrula, D'Orb.				×	
subteres, Brady				×	×
Virgulina Schreibersiana, Czjzek.					×
squamosa, D'Orb.				×	×
Bolivina punctata, D'Orb				×	×
dilatata, Reuss					×
pygmæa, Brady				×	×
ænariensis (Costa)					×
Cassidulina lævigata, D'Orb.	×	×	×	×	×
crassa, D'Orb.	×		×	×	×
Lagena globosa (Montagu)	×				
lævis (Montagu)					×
apiculata, Reuss		×			×

	A	B	D	C	E
Lagena acuta, (Reuss)				×	×
gracillima (Seg.)		×		×	×
marginata, W. & J.				×	
orbignyana, Seg.				×	×
distoma, P. & J.				×	×
striata (D'Orb.)				×	×
semistriata, Will.					×
sulcata (W. & J.)				×	×
pulchella, Brady					×
lineata (Will.)					×
melo (D'Orb.)					×
squamosa (Montagu)		×	×	×	×
lagenoides, Will.					×
hispida, Reuss					×
Nodosaria (*G.*) *lævigata*, D'Orb.			×	×	
(*G.*) *rotundata*, Reuss				×	
simplex, Silv.				×	
scalaris (Batsch.)	×		×	×	×
(*D.*) *communis*, D'Orb.			×		
(*D.*) *soluta*, Reuss					×
(*D.*) *pauperata*, D'Orb.					×
Vaginulina linearis (Montagu)		×			×
spinigera, Brady				×	
Marginulina glabra, D'Orb.					×
costata (Batsch.)					×
Cristellaria rotulata, Lamk.	×		×	×	×
cultrata (de Montfort)				×	
reniformis, D'Orb.				×	
Polymorphina lactea (W. & J.)	×			×	×
Uvigerina pygmæa, D'Orb.	×		×	×	
angulosa, Will.	×	×	×		×
Globigerina bulloides, D'Orb.	×	×	×	×	×
inflata, D'Orb.	×	×	×	×	×
bulloides, var. *borealis*	×	×			×
(*Orbulina*) *universa*, D'Orb.	×	×	×	×	×
Hastigerina pelagica (D'Orb.)			×	×	
Pullenia sphæroides (D'Orb.)			×	×	×
quinqueloba, Reuss	×		×	×	
Sphæroidina bulloides, D'Orb.	×			×	
Spirillina vivipara, Ehrenb.					×
Patellina corrugata, Will.					×
Planorbulina ariminensis (D'Orb.)	×			×	
(*Truncatulina*) *lobatula* (W. &. J.)	×	×	×	×	×
(*Tr.*) *refulgens* (de Mont.)	×	×			
(*Tr.*) *variabilis*, D'Orb.	×	×			
(*Anomalina*) *coronata*, P. & J.	×				
Rupertia stabilis, Wallich.		×			
Pulvinulina repanda (F. & M.)	×				
karsteni (Reuss)	×	×			
menardii (D'Orb.)	×				×
canariensis (D'Orb.)		×	×		
scitula, nov.			×	×	×
micheliniana (D'Orb.)	×			×	×
Rotalia orbicularis, D'Orb.			×	×	×
Nonionina stelligera, D'Orb.	×	×			
scapha (F. & M.)	×	×			
turgida (Will.)	×		×	×	×
umbilicatula (Montagu)	×	×	×		×
Polystomella striato-punctata (F. & M.)	×	×		×	×
Operculina ammonoides (Gron.)			×	×	

The following notes refer to species mentioned in the foregoing table, which are either new to science or otherwise present points of interest:—

Planispirina contraria (*Biloculina contraria*, d'Orbigny).—Dr. Steinmann (*Neues Jahrb. für Min.*, 1881, vol. i. p. 37, pl. 2), describes in detail the structure of the shell in this species, and shows sufficient grounds for separating it from the genus *Biloculina*. In point of fact, it is an intermediate sub-type, more nearly resembling *Hauerina* than *Biloculina*, but differing from the former in two important particulars, namely, the alar extension of the chamber-walls over the lateral surfaces of the test, which imparts to the shell a laminated structure like that of a nummulite, and the simple arched orifice instead of a cribrate aperture. On the basis of the former of these characters Dr. Steinmann proposes for it the generic term *Nummoloculina*.

My friend, the Rev. A. M. Norman, placed in my hands, long ago, some specimens dredged in the Faröe Channel, which were in the collection of the late Edward Waller. These belong to a closely allied species, and have been regarded as somewhat anomalous *Hauerinæ*. More recently, Professor Seguenza of Messina has had the goodness to send me examples of his *Planispirina communis* (*Mem. R. Accad. Lincei*, 1879–80, vol. vi. p. 310, pl. xvii. fig. 18), and I find them to be quite indistinguishable from Mr. Waller's unnamed form; in both the laminated structure is even more apparent than in *Pl. contraria*. Under these circumstances Professor Seguenza's generic term takes precedence of the more appropriate one suggested by Dr. Steinmann. The "Challenger" species described as *Hauerina exigua* (*Quart. Jour. Micr. Sci.*, vol. xix. n. s. p. 267) must be referred to the same genus; and there is still another more aberrant modification amongst the "Challenger" gatherings, to which the MS. name *Pl. sigmoidea* has been applied.

Cornuspira striolata, nov., resembles the typical *C. foliacea* in general characters, but the last convolution widens rapidly, spreading out and imparting to the test a contour very similar to that of the wide "bonnet-shaped" varieties of *Peneroplis*. The specimens sometimes attain extraordinary dimensions, the largest hitherto found being one from Station E, which measures more than an inch in diameter (1·2 inch or 31 mm.); a second, somewhat thicker proportionately, measures ·45 inch, or nearly 12 mm. Both of these have a surface ornament of fine, raised, closely-set striæ, parallel to the direction of growth, not absolutely straight and continuous, but taking a slightly waved and irregular course.

Cornuspira involvens, Reuss.—The specimens from both localities are somewhat doubtful; they have fewer convolutions than usual, and it is just possible they may be the tubes of minute annelids.

Cornuspira crassisepta, nov.—Convolutions very narrow and numerous, especially near the centre, as in *C. involvens;* but the peripheral edge is nearly square instead of rounded, and the spiral septal wall is thick, and marked externally by a raised limbate line. Diameter $\frac{1}{45}$ inch, or 0·56 mm.

This is the isomorph in the porcellanous series, of a somewhat rare perforate form, *Spirillina limbata.*

Rhabdammina cornuta, Brady.—This is the species previously described under the name *Astrorhiza cornuta* (*Quart. Jour. Micr. Sci.*, vol. xix. n.s. p. 43, pl. iv. figs. 14, 15), but the structure of the test accords better with the firmly-cemented shell of *Rhabdammina* than with the thick, loose, sandy investment of *Astrorhiza*, and its position has been changed accordingly.

Jaculella obtusa, nov.—Test long, cylindrical, nearly straight, consisting of a tapering tube, commencing in a small bulbous chamber, and gradually increasing in size to the opposite extremity, which is broad and open. Texture coarsely arenaceous, hard and firmly cemented; exterior rough. Length, $\frac{1}{3}$ inch, or 8·0 mm.

It is possible that this may be only a variety of *Jaculella acuta*, from which it differs chiefly in having a small inflated primordial chamber instead of terminating in a point, and in its generally more slender contour. Of all arenaceous Foraminifera *Jaculella* appears to have the hardest and most firmly cemented test; at any rate, it is the one of which it is most difficult to obtain a satisfactory section by ordinary methods.

Marsipella cylindrica, nov.—Amongst the Arenacea found in the material from D., are a number of delicate cylindrical tubes, of nearly even diameter, built up of short sponge-spicules laid side by side, and forming irregular, more or less interlacing tiers. The largest specimen is about a quarter of an inch (6 mm.) in length, and $\frac{1}{150}$ inch (0·17 mm.) in diameter, but such pieces can only be regarded as fragments of an organism that may be developed almost indefinitely. The species is manifestly closely related to *Marsipella elongata*, with which it is found associated. Similar fragments occur in one or more of the "Porcupine" dredgings, and less characteristic specimens at two of the "Challenger" stations.

Reophax difflugiformis, Brady.—There seemed a possibility that this species might turn out to be only the primordial chamber of *R. scorpiurus*, but as it exists in abundance in one of the dredgings (D) in which no specimen of the latter has been found, it is evident that it holds an independent position.

Reophax adunca, nov.—Test moniliform, consisting of a crooked line of inflated segments, irregular in size, but of nearly equal diameter. External constrictions between the segments comparatively slight; walls thin, rough externally. Length indefinite, specimens seldom found with either end entire; those which have been measured are about $\frac{1}{12}$ inch or 2 mm.

Reophax sabulosa.—This is the *Reophax rudis* of a previous paper (*Quart. Jour. Micr. Sci.*, vol. xxi. n. s. p. 49). The specific term *rudis* being preoccupied by a distinct form, figured by Costa as a *Nodosaria*, an alteration of name becomes necessary.

Haplophragmium tenuimargo, nov.—Test elongate, crosier-shaped, much compressed; lateral edges very thin. Spiral chambers few and small; linear segments about six in number, broad, slightly convex; septation obscure; aperture simple, irregular in form, terminal; texture coarse, surface extremely rough. Length of largest specimen, $\frac{1}{10}$ inch or 2·5 mm.

This is a somewhat rare species. Specimens have been met with at five of the "Challenger" stations in various parts of the world, at depths varying from 1000 to 3950 fathoms, but never more than one or two specimens from a locality.

Textularia aspera, nov.—An obscure few-chambered Textularian, with a loosely-made arenaceous test, not uncommon in some of the "Porcupine" dredgings, and often found parasitic upon *Rhabdammina*, occurs in the material from Station D. In localities where it is abundant, some of the specimens generally present triserial or Verneuiline characters. As it does not appear to have been described, I have given it the provisional name, *T. aspera.*

Cristellaria reniformis, D'Orbigny. — Under this species are included a group of large, flat, more or less carinate *Cristellariæ*, common at moderate depths in the North Atlantic, presenting every variety of contour from *Cristellaria compressa*, D'Orb., to *C. reniformis*, D'Orb. (*For. Foss. Vien.*, Pl. III. figs. 32, 33 and 41, 42).

Globigerina bulloides, var. *borealis*, nov.—In the fear of introducing unnecessary names, I have been unwilling to employ a distinctive term for the small thick-shelled *Globigerinæ* common in cold areas, if not peculiar to them; and they have been treated hitherto as starved examples of the species to which they seemed most nearly related from a morphological point of view, namely, *Globigerina bulloides* and *Gl. Dutertrei.* They are, however, very uniform in character, and the more they are studied the more distinct and easily recognised they become. It seems desirable, therefore, that their peculiarities should be embodied in a specific, or at any rate in a varietal, definition.

The test is of smaller dimensions than *G. Dutertrei*, the longer diameter of fully-grown specimens being about 3 mm. (that of the D'Orbignian species is 5 mm.), and it has fewer chambers, almost invariably four in the final convolution. The shell-wall is relatively much thicker and the aperture less conspicuous, but the habit of growth in other respects is very similar. Compared with *Globigerina bulloides*, the shell is more compactly built, its segments are less inflated and globular, and it has no umbilical vestibule. Under the name of "*Globigerina bulloides*, arctic variety," it is figured in the *Ann. and Mag. Nat. Hist.* ser. 5, vol. i. pl. 21, fig. 10.

Pulvinulina scitula, nov.—A variety of *Pulvinulina canariensis*, differing from the typical form in its relatively small size and compact habit of growth. The margin is rounded instead of sharp, and the peripheral ends of the chambers are only slightly convex instead of standing out prominently as in *P. canariensis.* Notwithstanding its small minute dimensions, it generally attracts attention by its glistening white appearance. Longer diameter, $\frac{1}{100}$ inch or 0·25 mm.

With one or two exceptions all these species, though some have been undescribed hitherto, occur in the material obtained on the "Challenger" and "Porcupine" expeditions, so that figures, as well as further details respecting their history and distribution, may be left until the publication of the "Challenger" report on Foraminifera. It may just be mentioned that the empty silicious tests of one of the *Phæodaria* (the form with Mr Murray's manuscript name *Challengeria naresi*) were found in the material from D and E.

Surface Forms.—There has not been time for the complete investigation of the gatherings made by the tow-net, and the following notes on the surface fauna are based upon the examination of about thirty mountings made by Mr Murray. As these are from material taken on nine different days, between July 27 and August 12, at various depths, from the actual surface down to 35 fathoms, and vary but little in the Foraminifera they contain, they are probably sufficiently representative.

The *Globigerinæ* are all referable to *Gl. bulloides*, *Gl. inflata*, and *Gl.* (*Orbulina*) *universa;* the specimens are small and thin-shelled, and those of *Globigerina* (proper) are non-spinous. The *Orbulinæ*, on the other hand, are sometimes armed with very short delicate spines. No specimens of *Globigerina borealis* occur in any of the surface mountings, and no *Pulvinulinæ*. The absence of the latter is in no way remarkable, for none of the species known to be pelagic are present in any considerable number in the dredged material; but that the small northern variety of *Globigerina*, which is tolerably abundant as a bottom species in three out of the five localities, should not be an equally prominent constituent of the surface fauna is a noteworthy fact.

Report on the Gas Contents of a number of Samples of Sea Water.

By Professor Dittmar, F.R.S.

The waters were left at my laboratory by Mr. Murray in the month of August.

In obedience to instructions received they were boiled out, the gases collected, measured, and analysed; care being taken to use the same methods as had served for corresponding work done in connection with the "Challenger" expedition.

The samples were contained in bottles of about one litre's capacity, provided with well-fitting glass stoppers. The bottles were almost full to the top; the empty air-space amounting to only 7 c.c. or thereabouts. The samples stood in my laboratory for some weeks before I received my orders as to what I should do to them; but they were carefully protected against direct sun-light, or elevation of temperature by other causes, and the stoppers never lifted before the contents were taken out to be worked up. Hence the dissolved gases are not likely to have changed much either qualitatively or quantitatively during the storage of the waters; the less so as the percentage of oxygen in the gas minus carbonic acid was in all cases found to be little different from what (according to my analyses of the "Challenger" water-gases) is generally met with in surface waters.

The boiling-out of the gases was effected by means of Jackobsen's apparatus, the flask of which held 740 c.c. of water. The flask in each case was charged by means of a long necked wide funnel going to the bottom of the flask; through this funnel water was run in until about 100 c.c. of water had run over the edge of the flask. This 100 c.c. of water, which was allowed to go to waste, could be assumed to include all that portion which was, to more than the absolutely unavoidable extent, affected by contact with the atmosphere of the laboratory. In regard to the rest of the work I may content myself with referring to my report on the "Challenger" gases.

Labels.

I. "Bottom Water No. 31; 11th August 1880. Depth, 515 fathoms."

II. "Bottom Water, No. 33; 17th August 1880. Depth, 540 fathoms."

III. "Bottom Water, No. 26; 4th August, 1880. Depth, 460 fathoms. Rona-Faroe."

IV. "Bottom Water; sounding No. 11; 28th July 1880. Depth, 270 fathoms."

V. "Bottom Water; 27th July 1880, Depth, 560 fathoms."

Supplementary label:—"This bottle was broken."

In the following statement of the results, Vo means the volume in cubic centimetres (reduced to 0° C., and 760 millimetres, and absolute dryness), of the total gas extracted from one litre of water. vo means the volume in cubic centimetres of the nitrogen and oxygen contained in those Vo c.c. of total gas, similarly reduced. So that Vo – vo represents the carbonic acid (in cubic centimetres and reduced as above) per litre of water.

	I.	II.	III.	IV.	V.
Vo, ...	24·49	25·47	18·77	20·08	22·12
vo, ...	13·92	14·80	13·74	15·95	14·40
Per cents. of CO_2 in Vo,	43·16	41·88	26·80	20·59	34·88
Per cents. of O_2 in vo, .	32·01	32·28	34·23	35·55*	32·88

* This number is *very* high; possibly it may be infected with an unobserved error. Unfortunately there was not enough of material to repeat either the boiling out or the analysis of the gas resulting from the one boiling.

(Signed) W. DITTMAR.

Note.—The percentages of CO_2 are rather high. The percentages of oxygen (in the gas freed from CO_2) are decidedly higher than those obtained for the "Challenger" waters from similar depths.

The high percentage of oxygen is owing probably to the relatively low values of the temperatures at which the waters originally absorbed their air, and the relative absence at their respective situations of decaying organic matter.

May 11, 1882. W. D.

Rocks of North Rona collected in August 1880 on the North-east Spur of the Island. By Prof. A. Renard and John Murray.

1. Amphibolic rock with a more or less schistose structure, fine grained, breaking in elongated fragments following the plane in which the crystals of hornblende are arranged. It contains especially black brilliant hornblende with the cleavages of 124° 30′. Also quartz and some grains of feldspar.

2. A rolled fragment of sandstone (Cambrian ?), red, fine grained, passing to arkose. This rock is essentially composed of fragments of quartz more or less rounded, of particles of hornblende, of epidote, of mica, and of more or less altered feldspar.

3. Gneiss composed of lamellæ of muscovite, plagioclase, orthoclase, and quartz.

4. Granitite containing plagioclase, orthoclase, quartz, and biotite.

5. Amphibolic rock, almost entirely formed of an aggregation of crystals of black hornblende, whose dimensions are from 0·5 to 1 centimetre, and show prismatic cleavage. Associated with the hornblende are granular quartz, lamellæ of biotite, and orthoclase.

7. Rolled pebbles of a clastic rock (Cambrian ?) composed of fragments of quartz, more or less rounded, and red orthoclase.

8. Gneissic rock formed of quartz, orthoclase, lamellæ of biotite, and rather large crystals of hornblende.

2. Notice of the Solar Eclipse of the 17th May, with Remarks on the Calculation. By Mr. Edward Sang.

The eclipse of the 31st December 1880 was not seen here, and thus we lost the opportunity of comparing the computed with the observed times.

In the daily papers at that time expression was given to a feeling of dissatisfaction that any computation should have been added to that recorded in the *Nautical Almanac.* And therefore, while laying before the Society the results at which I have arrived in regard to the coming eclipse, it may be proper for me to explain how such an investigation comes to be needed.

The moon's place is given in the *Almanac* to the tenth part of a second of arc, which distance is passed over in about one-fifth part of a second of time. Now with a telescope of moderate power, say 50, we are able to note the instant of contact to within a second; and hence, in order to get the full advantage of our comparison, the calculations must be made at least to the nearest second.

The elements of the eclipse are only useful for a preliminary determination sufficiently near to give the limits within which the strict calculations must extend; and the local times given for our principal observatories are only to tenths of a minute; hence it is that a working astronomer, even though he be at one of these observatories, must find means for a more minute determination; while we who are elsewhere placed must, of necessity, make the calculation for ourselves. The impossibility of having the details so given in the *Almanac* as to suit every observer, is obvious.

The accompanying six figures show the appearance which the sun will have, as seen from Edinburgh, at intervals of ten minutes from 6^h 30^m till 7^h 20^m on the morning of Wednesday the 17th; and the times of the principal phases, civil reckoning, are

First Contact	at	6^h	25^m	56^s
Greatest Phase	at	6	52	58
Last Contact	at	7	20	53

At the middle of the eclipse 200″ of the sun's diameter will be covered.

I have followed a method of computation differing somewhat from that usually adopted. It makes a considerable part of the work useful for all places, and avoids approximative formulæ.

The data given in the *Almanac* make it a very easy matter to decide on the limits within which the special calculations are to be made. In the present instance the times were taken at intervals of ten minutes from 18 20^m till 19^h 30^m Greenwich time.

The first step was to interpolate the sun's and moon's geocentric places, and to compute the moon's co-ordinates in relation to the earth's equator, to the meridian of a known observatory (Edinburgh), and to a plane perpendicular to these two. For this part of the work, we need the moon's distance, which has to be computed back from the parallax. I venture to suggest that it would greatly facilitate and improve the computation of eclipses and occultations, to have the logarithm of the moon's distance printed in the *Almanac*.

The next step was to transpose the origin of co-ordinates from the earth's centre to the place of observation. This is done by the simple addition or subtraction, as the case may be, of the co-ordinates of the locality, in which the earth's oblateness and even the height above the sea-level may be taken into account.

Lastly, from these local co-ordinates we deduce the moon's apparent position, distance, semidiameter and parallaxes. Hence the sun's parallaxes and apparent position, the distance between the centres and the separation of the limbs; the item last named being that which determines the eclipse. These results, with their differences, are as under :—

Gr. Time.	Separation.	δ^1	δ^2	δ^3
h. m.	″			
18 20	− 92·7	″		
		+146·8	″	
30	+ 54·1		−48·1	″
		+ 98·7		−4·5
40	+152·8		−53·6	
		+ 45·1		−2·6
50	+197·9		−56·2	
		− 11·1		+3·0
19 00	+186·8		−53·2	
		− 64·3		+6·7
10	+122·5		−46·5	
		−110·8		+9·2
20	+ 11·7		−37·3	
		−148·1		
30	−136·4			

From this we see that the first contact will happen between $18^h\ 20^m$ and $18^h\ 30^m$. Putting t for the time in minutes reckoned from the epoch $18^h\ 30^m$, and using differences of the third order, the separation has the value,

$$-\cdot 00091\dot{6}t^3 - \cdot 2405t + 12\cdot 366\dot{6}t_2 + 54\cdot 1 = \text{sep}^n = 0' .$$

Following my own method of solution, published in 1829, the operation is :—

−·0055	−·4801	+12·3667	+54·1000	0·
	+·0220	+ 1·9204	−49·4667	−4·
		− ·0440	− 3·8408	
			+ ·0587	
−·0055	−·4581	+14·2431	+ ·8512	−4·
	+ 3	+ 275	− ·8546	− ·06
			− 8	
			− ·0042	−4·06

Hence the first contact will be at

$$18^{h}\ 30^{m} - 4^{m}\ 03^{s}\cdot 6 = 18^{h}\ 25^{m}\ 56^{s}\cdot 4.$$

The greatest phase will be between $18^{h}\ 50^{m}$ and 19^{h}. Putting t for the time in minutes from the epoch $18^{h}\ 50^{m}$, the value of the separation is expressed by

$$+\cdot 00050t^{3} - \cdot 2810t^{2} + 1\cdot 6500t + 197\cdot 9 = \text{sep}^{n},$$

which is to be a maximum. We might equate the derivative of this to zero, thus obtaining a quadratic equation, but it is much more convenient for us to retain the cubic form and to determine t so as to render the derivative zero, thus :—

+·0030	−·5620	+1·6500	+197·9000	0·
	+·0090	−1·6860	+ 4·9500	3·
		+ 135	− 2·5290	
			+ 135	
+·0030	−·5530	− ·0225	+200·3345	3·
	− 1	+ 221	− 9	− ·04
		− ·0004	+200·3336	2·96

giving the time of the greatest phase

$$18^{\text{h}}\ 52^{\text{m}}\ 57^{\text{s}}.\ 6.$$

and the greatest eclipse 200″.

By this very short operation, we have solved the quadratic and substituted the value of its root in the cubic equation.

Counting the time in minutes from $19^{\text{h}}\ 20^{\text{m}}$, the equation for the last contact is

$$+\cdot 0015\dot{3}t^3 - \cdot 1865t^2 - 13\cdot 098\dot{3}t + 11\cdot 7 = \text{sep}^{\text{n}} = 0\,.$$

+ ·0092	− ·3730	− 13·0983	+ 11·7000	0·
	+ 83	− ·3357	− 11·7885	+ ·9
		+ 37	− ·1510	
			+ 11	
+ ·0092	− ·3747	− 13·4303	− ·2384	+ ·9
		+ 66	+ ·2417	− ·018
			+ ·0033	+ ·882

showing that the eclipse will end at

$19^{\text{h}}\ 20^{\text{m}}\ 52^{\text{s}}\cdot 9$ Green. M. S. Time.

Should favourable weather allow of a good observation, I shall compute the times for my own place, and submit the comparison to the Society.

3. Some Experiments on a New Secondary Cell.

By Mr. A. P. Laurie, B.Sc.

Last summer I communicated a paper to the Society on an Iodine Cell. This cell consisted of a carbon and zinc rod immersed in solution of iodine, in iodide of potassium. I found that iodide of zinc was equally suitable to dissolve the iodine in, as mentioned in that paper. While experimenting with this cell, the idea occurred to me of using it as a secondary battery. When the cell is exhausted, the whole of the iodine has combined with the zinc to form iodide of zinc. If an electric current is passed into this exhausted cell, the iodide of zinc is decomposed, zinc being deposited on the zinc plate, and iodine being set free at the carbon plate. The cell is now ready for use, and will give a steady current, having an EMF of 1·2 volts until the iodine is again combined with the zinc. I tried several experiments on this cell in Newcastle, with a view to testing its applicability to electric lighting as a storage battery.

In using a secondary battery for practical purposes, it is necessary to get a powerful battery of considerable storage into as small a space and weight as possible. The plates must therefore be brought close together. This makes it impossible to employ the usual methods for protecting the zinc plate by means of porous cells. A solution of iodine acts upon zinc to form zinc iodide, the rate of this action depending very much on the strength of the iodine solution. I directed my attention to finding out the amount of waste in the cell from this cause, and to finding out ways of checking it. I charged the cells with both battery and 'dynamo,' measuring the current put in and taken out on a voltameter, or charging two cells and using one at once, the other some hours afterwards. I had great difficulty in getting results from these experiments, and was at first deceived by the small waste in a cell partially charged. I ultimately found that in a fully charged cell I lost about $\frac{3}{4}$ of the full charge in a few hours. This enormous loss was due to the closeness of the plates, the strength of the iodine solution, and the porosity of the zinc deposit. The cell was also hot from the charging and subsequent running down. The great rapidity of the loss up to a certain point prevented me from discovering it at first. I used every method I could devise for checking the diffusion of the iodine to the zinc plate. The carbon plate was covered with powdered carbon to make a large absorbent surface for the iodine. It was then wrapped in a double layer of parchment paper, and placed in a narrow zinc box forming the other pole of the cell. The space between the carbon and the zinc ($\frac{1}{4}$ inch) was stuffed with paper pulp from the paper works, which pulp had been steeped in iodide of zinc. All this was done to check the diffusion of the iodine but it was useless.

I have found paper pulp very useful in batteries which have to be carried about. It is capable of holding 80 per cent. of its weight of water, when not squeezed. It is soluble in strong iodide of zinc, forming a transparent jelly, and turns black in the iodine solution, as does the parchment paper. Iodide of zinc, if exposed to the air in presence of paper pulp, sets free iodine.

From the above summary of my attempts, it is evidently hopeless to expect a practical secondary cell, in which the active agent is in solution. I accordingly tried to find some method for storing the iodine on the carbon plate in an insoluble form. It is unnecessary here to mention the various substances I covered the carbon plate with, in the hope that the iodine would form with them an insoluble compound easily decomposable. The only substance among those which I tried that worked at all was starch. This took up a certain amount of iodine when spread over the carbon plate in a thick paste, and the cell when thus charged gave a current. These experiments were, however, brought to a conclusion by my devising the cell which I now propose to describe in the remainder of this paper.

Cuprous Chloride Cell.—In this cell chloride of zinc is used, both because of its cheapness and of the higher electromotive force it gives. Iodide of zinc may also be used. The uncharged cell consists of two copper plates immersed in a solution of chloride of zinc. By passing an electric current through it, the chloride of zinc is decomposed, zinc being deposited on the one copper plate and chlorine being separated at the other copper plate. The chlorine never appears in the free state; it combines with the copper to form cuprous chloride, an insoluble white precipitate. The cuprous chloride is held against the copper plate by a sheet of parchment paper. This cell is now charged, and will supply a current until all the zinc is reconverted into chloride of zinc, and the cuprous chloride is reduced to metallic copper. The action of the cell is quite simple. As soon as the circuit is completed, the usual electrolytic state is set up. The chlorine of the chloride of zinc nearest the zinc deposit combines with the zinc, and the zinc separated at the other plate combines with the chlorine of the cuprous chloride to form chloride of zinc. It is a case of action at a distance, as in Grove's gas battery.

What is curious about it, to my mind, is that an insoluble non-conductor should enter so readily into the action of the cell. It must be remembered that the zinc is never separated; it takes up the chlorine from the cuprous chloride without ever appearing as zinc. It is impossible that it should appear as zinc, and it is therefore curious that it should ever reduce the cuprous chloride. The reduction of the cuprous chloride proceeds from the copper plate outwards. This question of what insoluble substances will enter into the action of a battery, and why they do so, is one of great importance, if primary batteries are ever to be cheap sources of electricity.

This cell may also be used as a primary battery, one pole being a zinc plate and the other a copper plate surrounded by cuprous chloride. It has this great advantage as a primary battery, there is no waste from diffusion of one liquid into another, as in the Daniell cell. It is a one-fluid battery. With this advantage it has also the advantage of the Daniell cell, in being free from polarization, and in no gas being given off during its working.

I measured its electromotive force on a Thomson electrometer, using a Daniell cell as my standard. Calling the electromotive force of a Daniell one volt, the electromotive force of my cell is ·75 volt. To return to the secondary cells. The first point I proceeded to investigate, was whether the cell lost its charge on standing. This would only take place in a properly constructed cell by the solution of the cuprous chloride in the chloride of zinc, and its diffusion to the zinc plate, where it would be reduced to metallic copper, chloride of zinc being formed, or by some local action at the zinc deposit, between it and the copper plate. This local action does exist to a very slight extent, the water itself or traces of other salts than chloride of zinc being the cause. Chloride of zinc itself cannot, of course, produce local action between zinc and copper. The other form of loss, namely, from the solution of the cuprous chloride, I investigated as follows:—I made up a small cell, by taking a copper and a zinc plate of about 4 square inches surface, with wires soldered to them, wrapping the copper plate in parchment paper, and tying it and the zinc plate together with thread, two slips of wood, about a ¼ inch thick, being put between them to keep them apart. This was then slipped into a small beaker, containing chloride of zinc solution, and a current passed through the cell from a bichromate battery, the zinc being deposited on the zinc plate. The chloride of zinc used was the commercial chloride, and this sample contained little or no lead and no copper. This cell was charged for about three hours, and then left standing for twelve hours. At the end of that time I tested the $ZnCl_2$ solution. It gave a brown coloration with H_2S, but no precipitate. The zinc deposit was then dissolved in HCl, and some small black flakes were left insoluble in boiling dilute HCl. These flakes dissolved on adding a little chlorate of potash, and the solution thus prepared gave a blue coloration with ammonia, and a very small black precipitate with H_2S. There was evidently, therefore, copper in the zinc deposit, but it was only a trace. Inside the parchment paper there was plenty of cuprous chloride, which was pure white, the parchment paper itself was green. I made several experiments of this kind; sometimes I found more copper than at others. On these occasions the parchment paper was green, showing the presence of oxychloride, and therefore of cupric chloride. This was caused, I believe, by air bubbles under the parchment paper. Any copper found on the zinc plate is more likely to be due to this than to solution of the cuprous chloride. If it is at all soluble in chloride of zinc in the cold, it must be very slightly so. This loss from copper chloride diffusing cannot be more than 5 per cent. of the charge in forty-eight hours; it is more likely in a properly made cell to be 1 per cent. or 2 per cent. It is difficult to settle its exact amount.

With reference to the formation of oxychloride, I noticed one remarkable phenomenon which I cannot explain. If moist cuprous chloride is exposed to the air, oxychloride is formed; but if the moist cuprous chloride is wrapped in parchment paper, and the outer surface of the parchment paper exposed to the air, the oxidation seems to go on through the parchment paper, and in a few hours the outer surface of the parchment paper is covered with a green slime of copper salts, that have in some way penetrated it.

To test the working of this battery, I made up some primary cells with cuprous chloride and zinc plates. In these cells I foolishly used linen to wrap round the cuprous chloride paste, and it came through in considerable quantities, thus causing a great deal of waste.

One of these cells was put on a voltameter consisting of two copper plates, "both weighed," separated by two strips of wood tied together with string, and immersed in a beaker of $CuSO_4$ sol. This I found forms a very good voltameter for rough purposes, and as the plates are very close together its resistance is low, which is of course important. By weighing both plates, and taking the mean, the results are fairly accurate. I used ordinary sheet copper, but no doubt electro-deposited copper would be better. I describe this form of voltameter, because the form described in Wiedemann's *Galvanismus*, namely, a platinum crucible with a silver rod in the centre, is only of use in very special and small experiments. It is very expensive and troublesome to work with. In this experiment, then, I found that after the cell had run six hours, the difference between the weight of zinc dissolved and the equivalent weight of copper deposited represented a loss of 15 per cent. 85 per cent. of the zinc dissolved had been returned as deposited copper, notwithstanding that I had used linen, which caused considerable waste. I then measured the internal resistance of a cell of 28 square inches surface, and having a distance of $\frac{1}{4}$ inch between the plates, and found it to be ·15 ohm. I have reduced the resistance very considerably below this in recent cells.

I also made up twelve primary cells of 28 square inches surface each, and used them to illuminate a small Swan lamp, measuring the current and the candle power.

These experiments also gave very satisfactory results.

When I began to charge one of these cells, however, measuring the current on a tangent galvanometer, I found to my astonishment, that the current, starting at the strength to be expected from the EMF of the external battery and the resistance of my cell, rapidly fell off, so that in a few seconds the current indicated an increase of resistance in the cell from a few tenths of an ohm to as much as thirty ohms. At this point the current would remain stationary. On now attaching the cell to the galvanometer a powerful current would flow from it, indicating that it had instantaneously returned to its normal internal resistance. At first I supposed that this was due to some polarization set up in the cell greater than the legitimate electromotive force of the cell. But it is impossible to suppose so high an opposing electromotive force being set up as this explanation would require, and there is nothing in the chemical reactions of the cell to account for it. I have also observed a cell get very hot under the influence of a powerful current, no doubt on account of its great resistance. I set to work to remove this difficulty in the use of the cell as a secondary battery, both chemically and mechanically. To remove it mechanically I increased the surface of the copper plate by covering it with precipitated copper. This was a great improvement, the resistance accumulating with comparative slowness. I found that the nature of the precipitated copper had a great effect, and at last got the best results by the reduction of a paste of cuprous chloride covering the copper plate. I reduced it by replacing the other copper plate with a zinc plate, and running down the cell thus formed. A firm spongy surface of copper was thus formed, usually red in colour. A still further improvement was made by covering this copper surface with a sheet of copper gauze, the copper gauze being soldered by wires to the copper plate. The purpose of this gauze was to produce two surfaces of action, one on each side of the precipitated copper, also to steady the current flowing from the cell when it was charged, by preventing its internal resistance from changing so much as it would otherwise have done. I have curves showing the gradual improvement in charging capacity of the cell. These curves were plotted after each experiment. I attach great importance to this surface of wire gauze, both in the primary and in the secondary cell.

The way I propose to use it in the primary cell is as follows:—Let us suppose a primary cell consisting of a jar containing cuprous chloride, with a copper plate round the inside as the one pole, and with a small porous pot in the centre containing a zinc rod and chloride of zinc solution. The resistance of this cell would be considerable at first, and as the cuprous chloride was gradually reduced from the copper plate in towards the centre, leaving behind it copper, the resistance of the cell would become less, and in this way a gradually increasing current would be supplied. But if we had a cylinder of copper gauze surrounding the porous pot, and in metallic connection with the copper plate, it would form another surface of action, and would keep down the resistance of the cell from the first.

I tried to reduce the accumulation of resistance chemically by introducing small quantities of various zinc salts. I found nitrate of zinc had a wonderful effect in preventing an accumulation of resistance though put into the cell in very small quantities. I suppose the nitric acid set free on the copper surface kept it clean from the skin of cuprous chloride, to which the accumulation of resistance is no doubt due. Unfortunately it seems to demoralise the cell. It is impossible to get the charge put into the cell properly and entirely returned. Why this should be I do not know. When I found the introduction of the nitrate of no practical use, I examined no further into its action. I have therefore had to be content with the improvement produced by the porous copper and the wire gauze. When the resistance has increased to such an extent as to cause a serious waste of the charging current, I consider the cell as fully charged. And I would here say, that in secondary batteries as at present designed, one of two things seems to be inevitable,—gas is given off, or resistance accumulates.

In the Planté cell the peroxide of lead formed is a conductor; consequently, when the surface exposed is nearly all oxidised, gas is given off the oxidised surface; to the modification of the Planté cell by M. Faure the same remarks apply. In my cell the substance formed is a non-conductor; no gas is given off, there is not even a smell of chlorine; but as the surface exposed is converted into cuprous chloride, resistance accumulates in the cell. These secondary batteries may simply be regarded as polarised plates, the amount of polarisation depending on the surface exposed. I am afraid, therefore, that it will be very difficult to store a large amount of energy in a cell of small surface and weight. The storage in the cells invented so far is miserably small, and mine is no better than the rest in this respect.

Another difficulty in this battery has been depositing the zinc successfully. It has a tendency to form bunches of crystals, which reach across the cell to the copper plate, and form metallic connection therewith. The charging current should not be too powerful, though a current of three or four times the EMF of the cell may be used, and it should be stopped when the resistance becomes serious. I will state at the end of the paper at what resistance I usually stop charging. The zinc should have a smooth surface, with no edges to deposit on. It deposits best on a horizontal plate, as might be expected, and I have some reason to believe deposits better for having light excluded. This point would require careful investigation. It is very difficult to insulate any part of the zinc plate. The zinc appears in bunches, having come through invisible holes. The only effective insulation I have found is sheet gutta-percha.

The form of cell I most frequently use is a tray cell. Thin sheet copper is folded at the corners on a wooden mould into a shallow tray, with sides sloping outwards. The bottom of each tray has stamped in it a depression about $\frac{1}{8}$ inch deep, across which is soldered copper gauze. The sides of the tray are carefully insulated with gutta-percha, and the solder varnished or plated with copper. The shallow depression is filled with cuprous chloride paste, through the holes in the wire gauze, and is then covered with parchment paper. Each tray is kept apart from the tray beneath by gutta-percha supports, or by a piece of old fishing-net. The cuprous chloride is reduced by means of zinc plates inserted into the trays, and the battery is ready for use. The only objection to the trays is the gradual formation of bubbles of hydrogen, when a charged cell is left standing, from the slight local action on the zinc plate. These bubbles cannot escape very readily, but it seems sufficient to slightly incline the cells. The electromotive force of this cell I have already stated. The plates may be brought very close together, as very little water is sufficient to dissolve all the chloride of zinc required. The resistance is consequently very low, a primary cell of 1 square inch surface having a resistance of 1·2 ohm.

At the end of this paper I give a summary of one experiment with a primary cell, and of two experiments with a secondary cell. The storage of this cell for a given surface is very small. This is to be expected, from what I have already stated about the limited storage of secondary cells. With so small an EMF as mine, it is not possible to store much on a given surface. The materials of my cell are so light, however, that I can store about 30,000 ft. lbs. for every lb. weight of metal in the cell.

In the primary cells the current is usually pretty steady until the cell is nearly exhausted, it then falls off rapidly. In the secondary cell it usually falls off from the beginning, or at any rate very soon after the cell begins to run down. This is due to increase of internal resistance from the using up of the cuprous chloride and the zinc. These cells usually run themselves out completely, leaving no zinc deposit.

To recapitulate the peculiarities of this cell. It is a one-fluid cell, and therefore does not suffer from diffusion.

Its internal resistance is very low. 1·2 ohm for 1 square inch surface. Its EMF is ·75 volt.

It does not suffer from polarisation, nor does it give off any gas either during charging or running down.

When being charged it increases in internal resistance.

The experiments on the next page are selected from many, as being fairly favourable specimens of the action of the cell.

I have not said anything here on my views of the practical application of secondary cells to electric lighting, or of how I propose to use my cell. I hope to be able to lay a future paper before the Society on this subject. I should mention that this cell has been patented in my name as a secondary battery by Mr. Swan of Newcastle.

Primary tray cell, 6 sq. in. surface,* weight = $\frac{1}{5}$ lb.
Current varying from 3·5 to 5·5 Ampères.
  1st minute, 4·2 Ampères.
  45th minute, 4 Ampères, then rapidly falling.
Average for 45 min., 4 Ampères.
Work expended in circuit = 5950 ft. lbs.
Average internal resistance, 0·2 Ohm.
16 tray cells occupying 4″ × 5″ × 4″, and weighing about 3 lbs., supported a small Swan lamp for 1 hour 10 minutes at 1 candle.

Secondary Tray Cells.

1st cell. Surface 7 sq. in., $\frac{3}{8}$″ between trays.
EMF of cell before use, 0·8 Volt.
After 12 minutes, current = 3·1 Ampères.
  EMF = 0·7 Volt.

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* By the "surface" is meant the surface of one plate, not of both together.

After 32 minutes, current = 2·2 Ampères.
EMF = 0·7 Volt.
After 52 minutes, current = 1·3 Ampères.
Work expended in circuit = 3560 ft. lbs.
2nd cell. Surface 7 sq. in.
After first minute, current = 0·4 Ampères.
After 30 minutes, current = 2·5 Ampères.
Work expended in circuit = 2880 ft. lbs.

Monday, 5th June 1882.

THE RIGHT HON. LORD MONCREIFF, President, in the Chair.

The President read Obituary Notices of Mr. David Smith, Dr. William Lauder Lindsay, and Professor Benjamin Peirce, deceased Fellows of the Society.

OBITUARY NOTICES.

DAVID SMITH. By Mr. David Maclagan.

Mr. DAVID SMITH was born 13th January 1803, and died 16th December 1880, in his 78th year. He was educated at the High School and University of Edinburgh, his native city.

Having resolved to adopt law as his profession, he joined the body of Writers to Her Majesty's Signet in 1826, and at a comparatively early period of his life acquired an outstanding position as a man of business. Large and important interests were committed to the charge of his partner, Mr. James Kinnear, and himself, involving increasingly from year to year much laborious care and watchfulness.

In the year 1858 he was offered, as affording by its more defined and systematic duties, some measure of relief from an overtasked life, the vacant appointment of principal officer of the North British Insurance Company; his wide general experience having included a practical acquaintance with the principles and management of life assurance companies. He threw himself with characteristic energy into this new sphere of labour, and, under his guidance, the company, which had always held a high place among similar institutions, rose with rapid strides to a position of preeminence.

The labours of a crowded business life of half a century at last began to tell upon his health; and in the year 1880 he resigned his office, and retired from active business, receiving from a very wide circle in our city expressions of sympathy, respect, and gratitude.

While immersed, as might have been supposed, in purely professional work, Mr. Smith took an active and effective part in connection with a vast variety of matters affecting, in different relations, the interests of Edinburgh, and indeed of Scotland.

As a Justice of Peace and Deputy-Lieutenant of the city of Edinburgh, he identified himself with every movement fitted to further its prosperity and good government.

Educational questions had always a special place in his regard; and any movement designed to promote the advancement of the University, in the way of enlarged endowments or of extension of its range of teaching, received his steady support.

Philanthropic and benevolent institutions—notably the Royal Infirmary—secured much valuable service at his hands, while at the same time he was busy with ecclesiastical affairs in connection with the Established Church of Scotland, of which he was an office-bearer, and in the interests of which he was a much valued counsellor and an unwearied worker.

Our own Royal Society derived no small advantage from his tenure of the office of Treasurer during a long series of years.

In a variety of qualities, not always, and indeed not often found in combination, we have the secret of his power of discharging, with a large measure of effective success, the many and diversified duties which seemed to fall to him with a certain naturalness and propriety.

It was impossible not to be struck by the keen insight and rapidity of decision which characterised his examination of any subject brought before him. The matter being disposed of, it was dismissed and forgotten, and some new and quite different question or interest followed a like course with equal despatch and determination. That there were disadvantages attending this habit of mind is undoubtedly true; but, in the main, it enabled him to overtake an amount and range of work quite remarkable in its extent and variety.

His administrative talent was conspicuous; and in work which brought him in contact with large numbers of persons of diverging views and opinions, his genial presence and firm attitude often secured united action, and moderated with singular success in divided counsels.

His courtesy of manner, kindness of heart, and obviously earnest desire to be helpful, attracted towards him the confidence and affection of a wide circle of attached friends.

Broadly viewed, few more useful lives have been spent in the community of which he was a member, and still fewer have commanded for themselves so much influence and regard as to leave, as he has done, a vacant space in society, which it is not probable we shall soon or easily see adequately filled.

WILLIAM LAUDER LINDSAY. By Dr. W. C. M'Intosh, F.R.S.

Dr. **WILLIAM LAUDER LINDSAY** was born at Edinburgh on the 19th December 1829, and received his education at the High School. He had naturally strong tastes towards botany and geology, and had collected plants even before entering the University as a student of medicine in 1847. During his medical curriculum his botanical tendencies received a great impetus, as he himself records, from Professor Balfour, in whose classes for two summers he carried off high honours. Some of his beautiful dissections of grasses are still justly admired in the Museum in the Botanic Garden. After a career in which he distinguished himself as a zealous and industrious student, he graduated as Doctor of Medicine in 1852, his thesis being on the "Structure and Physiology of the Lichens." This essay and its illustrative preparations received the high commendation of the Medical Faculty. He soon after competed for the Conservatorship of the Museum of the Royal College of Surgeons, Edinburgh, but the late Professor Sanders obtained the post. He then became Resident Physician in the Cholera Hospital, Surgeon's Square, under the amiable and accomplished Dr. Warburton Begbie, and while in this position his perseverance and acute powers of observation enabled him to make a series of interesting experiments on the communicability of cholera to the lower animals. These researches attracted considerable notice in the medical papers both at home and abroad.

Dr. Lindsay thereafter entered the Crichton Royal Asylum, Dumfries, as Assistant Physician, his chief being the able and genial Dr. W. A. F. Browne, the brother-in-law of his botanical patron. This seems to have been the turning-point in his career, as it is unlikely he would have left the arena of pure science if there had not been a paucity of suitable appointments in the botanical or other department. While doing duty in his new office in a manner that gained him much approbation, he received, at the instigation of the late Dr. Malcolm of Perth, the appointment of Resident Physician to Murray's Royal Asylum, Perth, at the end of 1854; and for a quarter of a century he laboured with unflagging zeal to promote the welfare of his patients and the interests of the institution, until failing health compelled him to resign at the end of 1879.

Few physicians in our country have been gifted with a pen so facile, an intellect so varied, and a perseverance so unbroken as that of Dr. Lauder Lindsay. The mere list of his literary and scientific publications would form a considerable pamphlet, the chief articles grouping themselves under the heads of Botany, Medicine, and General Literature. It must be remembered, also, that his scientific work was accomplished after his energies had been spent in continuous and responsible duty, and at a distance from scientific aid and encouragement. His medical writings, including his laborious work on *Pensions to Asylum Officers*, and the collection of incidents massed in his *Mind in the Lower Animals*, have already received notice in various Journals (*e.g.* the *Edinburgh Medical Journal* for January 1881), so that on the present occasion attention will be directed to his more strictly scientific labours.

Eager to add to existing botanical knowledge, he very early in his career, at the suggestion of Professor Balfour, chose the Lichens as a suitable subject for investigation, and soon after graduation he published a *Popular History of British Lichens*, illustrated by many plates. This little work received very favourable notice, and is still a useful guide on the subject. A series of structural and other papers on the Lichens then followed, several being communicated to this Society. For one of these, viz., his Memoir on the Spermogones and Pycnides, the Neill Prize was awarded in 1859. His various papers were illustrated with plates drawn by himself, and though the nature of his subject did not admit of much artistic display, his representations were both accurate and well finished. His labours amongst the Lichens did much to place the study of that department on a scientific basis, and greatly extended our knowledge of their structure and economy.

In his early days a considerable traveller, he explored the mineralogical and geological features of the Hartz mountains, and made large collections. He also in subsequent years visited many other places on the Continent, besides Iceland and the Fæ̈roe Islands, America, and Egypt. Moreover, his health, which had never been robust, failing in 1861, he obtained a year's leave of absence, which he spent in visiting New Zealand and Australia, making extensive collections, and laying the foundation of many papers on the Botany and Geology of New Zealand. He also stimulated the colonists by a lecture, at Otago, on "The Place and Power of Natural History in Colonisation." In the same way his visits to Iceland and the Fæ̈roe Islands formed the basis of several botanical and geological papers, and subsequently enabled him to deal more easily with the Lichen-flora of Greenland.

In viewing the number and variety of Dr. Lindsay's botanical and geological communications, one is struck by the extraordinary industry that characterised him. His active mind was ever on the stretch, and his facile pen never failed to make the best use of the materials at his disposal. The field covered by his labours, however, was much too extensive for the production of work of equal value in every case, and the pressure on his time occasionally prevented the necessary consolidation of prolix articles. Taken all in all, however, his botanical labours do him infinite credit, and have greatly advanced the subject he took under his care. It will be long before the Lichens find so able and so accomplished a worker. He was, indeed, the Nylander of Scotland. In accordance with his instructions, his valuable collection of Lichens was presented by his trustees to the University of Edinburgh, and is now in the Museum in the Botanic Garden.

As a public official in the Perth Royal Asylum, his bearing and administration were admirable; nor were his relations in private life less worthy of esteem. He placed the institution on a sound basis financially, in his early years, and reorganised every department; while in his later years of office he greatly improved and beautified the internal arrangements of the various wards, and he did so with uncommon ingenuity and taste. Shrewd and acute to an extraordinary degree, he proved himself a most accomplished alienist-physician, kind and considerate to his patients, skilful in promoting their comfort and recovery, and an apt organiser of all the events that constantly take place in such institutions. His thorough medical training, and his natural penetration, made him always a safe and prudent adviser.

Originally of a slight build, his intense application to work caused his health to give way after his marriage in 1859, and even the improvement gained by the year's relief in 1861–62 gradually wore off on the active resumption of literary and official engagements. Indeed, for years before his death he was an invalid. Yet he bravely did his duty to the last, and kept a cheerful word for every one—even while he doubted if his strength would enable him to conclude his visit. Probably for the same reason he avoided society, solacing himself rather with his books and microscope. His health unfortunately showed no sign of improvement, and he had hardly been a year out of office when he succumbed to the increasing exhaustion on the 28th November 1880, at the comparatively early age of fifty-one. Much of the work his ardent mind sketched out for himself he left undone; but he achieved enough to win a solid reputation, and to furnish a worthy example of what ability and application can do under difficulties.

Professor BENJAMIN PEIRCE. By Professor Simon Newcomb.

PROFESSOR PEIRCE was born at Salem, Massachusetts, April 4, 1809, and graduated at Harvard College in 1829. He made the acquaintance of Dr Nathaniel Bowditch, the translator of the *Mécanique Céleste*, and assisted him in getting his great work through the press. He spent two years after his graduation in teaching. He was appointed tutor in mathematics at Harvard

College in 1831, and professor in 1833. During the few years following he published a series of mathematical books covering the course then taught at the college from Algebra to Differential Equations. His elementary books were remarkable for their condensation. In the geometry, especially the short and terse and comprehensive forms of mathematical thought and expression, natural to the mathematician, were substituted for the minute demonstrations of Euclid. Free use was also made of infinitesimals. The volumes of geometry and the infinitesimal calculus were published under the title of *Curves*, *Functions*, and *Forces*. The subject of Forces, which was intended to cover mechanics, was, however, dropped from the series. The concluding portion of the second volume is devoted to the Differential Calculus, and is noteworthy for the brevity and conciseness of style, and the free use of operative symbols.

After the death of Bowditch in 1838, Peirce stood at the head of mathematical science in his country, as the leading one of the very few who had access to foreign journals. About 1842 he commenced, in connection with Professor Lovering, the publication of a serial under the title of the *Cambridge Miscellany of Mathematics* and *Physics*, of which, however, only a few numbers appeared. He took an active part in the foundation of the Harvard Observatory, the occasion being afforded by the great comet of 1843. The work which first extended Peirce's reputation, was his computation of the general perturbations of Uranus and Neptune. The formulæ to which he was led were published in the first volume of the *Proceedings of the American Academy*, but were accompanied by no description of his process. Subsequent investigations, however, showed them to have been remarkably accurate. In his views of the discrepancy between the mean distance of Neptune as predicted by Leverrier, and as deduced from observation, he was less fortunate, although, when due consideration is given to Leverrier's conclusions, there was much plausibility in the position taken by Peirce. As the subject has frequently been discussed without a due comprehension of all the circumstances, a brief review of them may be appropriate.

Leverrier, from his researches, found for the mean distance of the disturbing planet 36·1539, and a consequent period of 217 years.

He also announced that the limits of the mean distance which would satisfy the observed perturbations of Uranus were 35·04 and 37·90. He founded this conclusion on a supposed inadmissible increase of the outstanding differences between theory and observation, as the mean distance was diminished below 35. But when the planet was discovered its mean distance was found to be only 30; and yet the observations of Uranus were as well satisfied as by Leverrier's hypothetical planet. It was, therefore, an expression of Peirce's high confidence in the accuracy of Leverrier's conclusions that led him to announce that there were two solutions to the problem; the one being that found by Leverrier, and the other that corresponding to the actual case. He also sought to show a cause for the two solutions in a supposed discontinuity in the form of the perturbations, when the period was brought to the point at which five revolutions of Uranus would be equal to two of Neptune. As a matter of fact, however, it has been shown by Professor Adams that there was no such discontinuity in the actual perturbations during the limited period; from which it would follow that Leverrier must have made a mistake in tracing out the conclusions which would follow when the mean distance of the disturbing planet was diminished.

In 1849 the preparation of the *American Ephemeris and Nautical Almanac* was commenced at Cambridge, by Lieutenant C. H. Davis, and Peirce, in the capacity of consulting astronomer, took an active part in planning the work. It being especially desired that accurate tables should be employed in the new *Ephemeris*, Peirce made use of Airy's reduction of the Greenwich lunar observations, then recently published, to prepare new tables of the moon. He prepared the formula and plans for the table which were executed in the office of the *Ephemeris*. *Gould's Astronomical Journal* was commenced at this time, and Peirce contributed a number of short papers, the most important of which related to the theory of Saturn's rings. The suspicion had been expressed by Bond and others, that temporary divisions took place in the rings from time to time, thus showing that they could not be solid. Peirce showed that the equilibrium of a fluid ring was necessarily unstable, as well as that of a solid one, and therefore suggested that the equilibrium was preserved by the attraction of the satellites. The research, however, was left in an unfinished state, but taken up some twelve years later in the first volume of the *Memoirs of the National Academy of Sciences.*

Among all of Peirce's contributions to science, that which he himself seemed to value most highly was his *Linear Associative Algebra,* which, however, was only published by lithographing and privately distributing a few copies. It essayed a general theory of the multiplication of units of different classes, subject to the law of association and distribution, but not of commutation.

In 1867 he was appointed Superintendent of the Coast Survey, to succeed Professor Bache; but finding administrative duties little to his taste, he resigned in 1874.

During the last few years of his life a tendency towards speculation, partly of a philosophic and partly of a cosmological character, which he had exhibited during most of his life, showed itself yet more strongly. He delivered before the Lowell Institute a course of lectures on Ideality in Science which have been published in book form, and afford an interesting view of the speculative operations of his mind.

The influence exercised by Peirce on the progress of mathematical science in his own country, is at least equal in importance with his scientific work. He was an ardent and enthusiastic friend, ever ready to encourage younger men and promote their work. He had an especial fondness for seeking out comparatively unknown men whose ability had been overlooked. As a teacher, he was very generally considered a failure. The general view he took was that it was useless for any one to study mathematics without a special aptitude for them; he therefore gave inapt pupils no encouragement, and made no attempt to bring his instruction within their comprehension. His extreme generality and terseness of expression, and his fondness for brevity of notation, sometimes made it difficult even for an expert to follow him; while a certain imaginative and poetic vein, in which his fundamental principles are laid down, was unsuited to most minds. The most characteristic as well as the most extensive of his works is his *System of Analytic Mechanics.* The exposition of dynamical concepts in the first forty pages is pleasant reading for one already acquainted with the subject, but that a student beginning the subject could understand it without a clearer distinction between definitions, axioms, and theorems seems hardly possible.

BOULDERS NEAR BEN NEVIS

Pro Roy Soc. Edin

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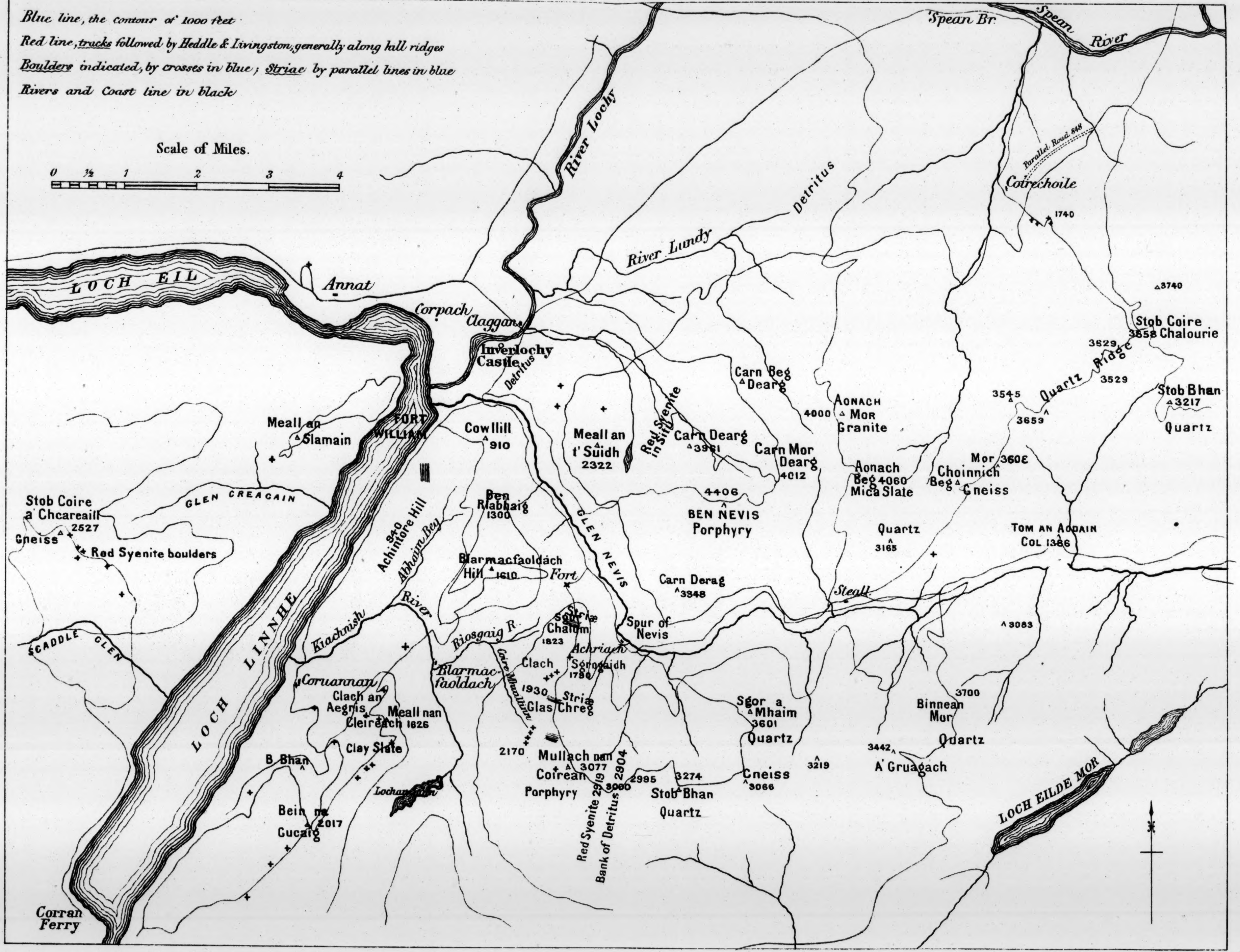


W. & A. K. Johnston, Edinburgh

The President announced that the Council had awarded the Keith Prize, for the Biennial Period 1879–81, to Professor Chrystal, for his paper "On the Differential Telephone," published in the Society's *Transactions* for the Session 1879–80; and the Neill Prize, for the Triennial Period 1877–80, to Mr. John Murray, for his paper "On the Structure and Origin of Coral Reefs and Islands," communicated to the Society on 5th April 1880, and printed (in Abstract) in the *Proceedings* for that date.

The President read a letter from M. Dumas, perpetual Secretary of the Academy of Sciences, Paris, inviting the Fellows of the Society to subscribe to a Fund to be formed, in order to present to M. Pasteur a Medal, commemorative of his work and services. Professor Tait announced that the Council had replied to M. Dumas' letter, informing him that the Society has no funds which can be devoted to such a purpose, but that an opportunity would be given to individual Fellows of subscribing to the Medal to be offered to M. Pasteur.

The following Communications were read:—

1. On Mirage. Part II. By Professor Tait.

2. Report of the Boulder Committee, with Remarks by the Convener, Mr. Milne Home. (Plate V.)

The Convener being now no longer able to climb hills, or walk to any considerable distance, his own contribution of information to the Committee is, this year, exceedingly small.

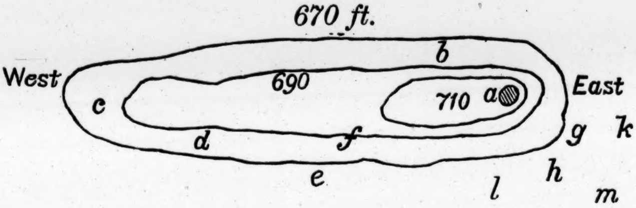
I. CANTIRE.—LOCH TARBERT.

The only place visited by him during last autumn was East Loch Tarbert, Loch Fyne, at the suggestion of Mr. Alexander of Lochgilphead, whose services to the Convener during the two previous years were peculiarly valuable.

Having procured a horse, the Convener, under Mr. Alexander's guidance, rode up two-thirds of a hill, about two miles to the N.W. of East Loch Tarbert, on the property of Mr. Campbell of

Stonefield. He omitted to record the name of the hill. The object was to examine a boulder bearing the name of "*Cappull-na-Cloiche*," meaning "The Mare of Stone," from its fanciful resemblance, in a misty day, to a mare feeding. The hill was found by aneroid to be 710 feet above the sea.

The summit of the hill is shown by the following diagram, not drawn to an exact scale:—



The length of the crest is about 60 yards in an east and west direction, along the contour line of 690 feet; and about 15 yards between N. and S. at *f*. The largest boulders are represented by the letters *a* to *m*.

The boulder with the name above mentioned (*a* in the diagram) stands on the very highest peak of the hill. It is composed of compact gneiss, whilst the rock of the hill is clay slate, with numerous quartz veins. The height of the boulder is 8 feet, and its breadth or width each way, near the lower end, is 5 feet.

There are multitudes of boulders near the top of the hill,—chiefly on the S.E. side, *g*, *h*, *k*, *l*, *m*. The largest of these, *k*, is 14 × 9 × 8 feet. There is only one boulder on the north side, viz., *b*, whose size is 9 × 4 × 4 feet. They are all gneiss boulders.

As bearing on the question of transport, it is proper to mention that this hill stands by itself, in a sort of amphitheatre. There are no hills so high as it within a mile.

At about that distance towards the north, there is a range of hills somewhat higher,—with openings between, especially towards the west. On these hills, numerous boulders were descried through the telescope, and regret was felt at the inability to visit them,—especially as several were seen perched on ridges and peaks.

It seemed probable, that if there had been ice carrying boulders, floating on a sea from 800 to 1000 feet above the present sea-level and stranding on the hill, the position of the boulders on the hill and its sides might be accounted for.

In this district, with hills, none exceeding 1200 feet in height, local glaciers are not likely to have been formed; and if there had been such, they would have passed down the low grounds on each side of the hill along its base.

On his way back to Tarbert, the Convener passed a conical hill, on south, clad with smooth green pasture. On its N.W. slope, two large boulders were observed. But as the access to the hill was difficult, the Convener did not attempt to reach it.

The hills, both north and south of East Tarbert, are well covered by boulders, and would repay a special visit from any one interested in this subject. Even from the streets of the town, in a clear day, boulders can be seen along the ridges of the surrounding hills on the sky-line.

On the hills adjoining East Tarbert village, on the south, and at a height of from 280 to 300 feet above the sea, there are evident marks of some agent having swept through between the hills from west to east. The rocks are well rounded by friction; and on the east side of many rocky knolls, there are small boulders, and heaps of gravel, which look as if they had been protected by these knolls from a westerly debacle or current.

The Convener, when at Rothesay, walked along the course of the small stream which runs into the sea near the Queen's Hotel. In the lower part of its course, the stream cuts through beds of gravel, from 50 to 60 feet thick. In the upper part of its course he came to a flat about 780 feet above the sea. He found there a number of boulders. The largest 4 × 2 × 2 feet, had its longer axis pointing N.W. and S.E.

Mr. Alexander told the Convener of a large boulder, 9 or 10 feet high, on the Farm of Taynish, at the head of a small arm of the sea, on Loch Sweyn, about 4 miles south of Tayvalloch. It is surrounded by a cluster of smaller boulders. It lies on bare rock, which slopes down towards the west. It is about 50 feet above sea-level. On the east side of it, there is an old sea bank, which may have intercepted its transport farther eastward.

II. Ochil Hills.

The Convener has received a letter from James Johnstone, Esq., of Alva, referring to the south slopes of the Ochil Hills, mentioning that the boulders in Alva Glen and Silver Glen are mica schist. In Tillicoultry Glen, he says there used to be many granite boulders; but he thinks they have all been broken up for building purposes.

He adds, that as the rocks of the Ochils are here a species of trap, the boulders in question probably came from the Grampian Hills, *i.e.* from the N.W.

III. Orkneys—North Ronaldshay.

The Convener has received the following in answer to the circular sent out by the Committee during last winter:—

"In this island of North Ronaldshay, Orkney, of which I am proprietor, and the rocks of which consist of Old Red Sandstone flags, there are no boulders that I know of. I have, however, observed a mass of coarse conglomerate, like a rock which occurs to the S.W. at Heclabir, in the adjacent island of Sanday.* It had been built into a stone dyke, and was of a size too large for most men to carry. The surface was slightly worn, but not rounded like a beach stone. I have also often found smaller blocks of granite and syenite (which may have been transported from Stromness in the Island of Pomona, also to the S.W.); and also a stone resembling coarse jasper, scattered over waste parts of the island. These are often more than half buried in the ground, and most of the blocks are more angular than beach stones. Some of them have their surfaces flattened and smooth, and in one or two instances shining, as if ground and polished. The soil on which they are generally found, is clay, loam, or nearly pure clay of a red colour; and sections in making quarries show, that it contains in places rounded pebbles with here and there angular flints, much discoloured, and bits of mica schist mixed with quartz and other extraneous stones. This red clay extends over many acres, and varies from 1 to 4 or 5 feet in depth.

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* *Note by Convener.*—Sanday Island is 5 or 6 miles from Ronaldshay. Stromness is at the S.W. end of Pomona, and about 40 miles from Ronaldshay, with deep seas between, and several small islands. Stromness is the only locality in the Orkneys for granite and syenite. In Sanday, there is the remarkable granite boulder weighing about 9 tons, which is referred to in the Committee's Second Report, p. 168.

"WM. TRAILL of Woodwick."

8*th March* 1882.

IV. SHETLAND.

1. *Parish of Lunnasting.*

In reference to the circular lately received asking for information about boulders, I beg to forward a few particulars respecting four. They are all in the parish of Lunnasting, on the estate of Lunna, and the property of Robert Bell, Esq., sheriff of Falkirk.

No. 1. Height 22 ft. 9 in.; length 36 ft.; breadth 25 ft.; shape, angular; direction of longest axis S.E. and N.W.; height above sea-level 150 to 200 ft.

No. 2. Height 19 ft.; length 34 ft.; breadth 14 ft.; angular; direction of longest axis N.E. and S.W.; height above sea-level 150 to 200 ft.

No. 3. Height 11 ft. 4 in.; length 8 ft. 7 in.; breadth 8 ft. 2 in.; angular; direction of longest axis S.E. and N.W.; height above sea 150 to 200 ft.

No. 4. Height 7 ft. 10 in.; length 8 ft. 7 in.; breadth 3 ft. 2 in.; wedge-shaped; direction of longest axis S.E. and N.W.; height above sea 300 to 400 ft.

Nos. 1, 2, and 3 stand all near each other in the northern part of the parish, and not far from the sea. Nos. 1 and 2 are separated only by a distance of 10 or 12 feet, the intervening space being filled with large masses of stone which appear to have fallen from No. 2. No. 4 stands by itself, surrounded by deep moss, within a few yards of the highest point of a hill about four miles to the south of the other three. Its longest axis runs parallel to the face of the hill. It is known by the name of the "standing stone" of the south hill of Lunna.

No. 3 has no special designation.

Nos. 1 and 2 are known as "the stones of Stofas." "Stofas" is said to be a corruption of *stay fast*, and the legend accounting for the name is that it was given to the stones from the circumstance that they were originally two giants passing through Lunnaness, and converted into stone by some superior power who arrested their progress by pronouncing the words "stay fast."

All the above stones look something like pale granite.

GEO. CHRISTIE.

The Manse, Lunna, Lerwick, Shetland,
18*th March* 1882.

Note by Convener.—The stones of Steffis are referred to by the late Dr. Hibbert in his quarto volume on Shetland (published in 1822), p. 173, where also a diagram of them is given, and an intimation of his inability to say more about them than that they "were enormous detached masses, which do not seem to have undergone any very distant removal, since they repose on rocks of a similar kind." In a paper in the *Edinburgh Journal of Science* for 1831 (vol. iv. p. 88), written by Dr. Hibbert (as he observes) twelve years after his first visit, he offers an opinion, which he says he is now "disposed to pronounce with some degree of confidence." "These immense boulders (he says) are in an elevated situation upon a very narrow tongue of land, 3 or 4 miles in extent, which having jutted out into the ocean in a N.E. direction, would be opposed to the direct force of the diluvial wave. The extremity of the headland being much broken, an indication is thereby afforded of the site *whence* these stones have been *dislodged* and by diluvial currents *hurried along*. The distance (he adds) to which they have been detached cannot be estimated at more than a mile or two."

These remarks are interesting, as indicating Hibbert's opinion, after a second visit to the spot, that the "stones" had been disrupted by some tremendous agency moving in a direction from N.E. towards S.W. and carried to a distance of "a mile or two." When Hibbert wrote in the year 1831, he not unnaturally, for boulder transport, adopted the theory proposed by Sir James Hall of Dunglass in 1812, of oceanic waves sweeping across continents. It was not till many years after, that ice was suggested as a medium of transport.

Hibbert, after referring to these stones of Steffis as "immense boulders," "detached" and "hurried along" from the headland of Lunna, goes on (by way of confirming his opinion) to cite several other cases in the Shetlands of the transport of boulders, which are extremely interesting.

Thus, he says, that on the Island of Yell, there are "large fragments of Serpentine and Euphotide, which have evidently been drifted some miles, from the islands of Unst and Fetlar."

"On the summit of Roeness Hill, composed of red granite," there is an "immense quantity of boulders of a primary greenstone which appear to have been removed from a site 2 or 3 miles off, and to have been rolled in a S. or S.W. direction, up a gradual ascent of 3 or 4 miles."

"On the summit of Hilswick Ness, we meet with a surprising block, composed of granite, removed from a rock, the nearest site of which is about 2 miles to the N."

He had previously mentioned that, in the Island of Papa Stour, there are "numerous fragments of hornblende schist and actinolite schist"—"rocks which are nowhere to be met with in this archipelago, except at Hilswick Ness, a distance (when measured in a straight line across the Bay of St. Magnus) of at least 12 miles."

Dr. Heddle of St. Andrews informs the Convener, that he, some years ago, examined these "*Stones*," and formed an opinion that they had, by some natural agency of great power, been detached from a rocky cliff not far distant, and been moved in a direction towards E.S.E. They are a peculiar micaceous gneiss, containing nodules of white felspar.

These "Stones" are referred to in the Second Report of the Boulder Committee, p. 178.

2. *Parish of Fair Isle.*

The Rev. William Laurence, catechist and teacher, reports as follows:—

"There are no boulders above 10 tons, but there are several small ones of the pudding-stone description, quite different from the rocks *in situ*. There was one very remarkable large stone—a huge block of sandstone—quite similar to the "*Eday*"* sandstone, but it was blown up by gunpowder last year, for building purposes. There was nothing like it in the whole island.

"It and the other small ones are probably glacial deposits."

V. CAITHNESS.

The Rev. Hugh Mair sends the following answers to a circular from the Committee:—

"Boulder in Keiss parish; estate of Freswick; farm of Mr. Peter Gunn; proprietor, Wm. S. Thomson Sinclair, Esq.

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* *Note by Convener.*—The Island of *Eday* is about 13 miles to the S.S.W. of *Fair Isle*. In the Geological Map of the Orkneys, lately published by Messrs. Peach and Horne (*Quart. Jour. of Lond. Geol. Society* for Nov. 1850), the rocks of "*Eday*" are represented as consisting of old red sandstone conglomerate. The geology of "*Fair Isle*" is not given by these gentlemen.

"Length 9 ft.; breadth 5 ft.; height 7 ft.

"Rounded, but rather broader at base.

"Longest axis W. by N. and E. by S., or W. and E.

"Different from any rock in locality; none similar in locality so far as known.

"Conglomerate or pudding-stone of a most remarkably pronounced character.

"Popular name, "Greystone"; no legend, save that it is called one of the Kirk stones,—origin of name unknown.

"200 ft. above sea-level; and ¼ mile from sea on east coast.

"Marks the boundary between the old parishes of Wick and Canisbay, and between the lands of Nybster and Aukingill.

"I am sorry to say the answers refer to the stone *as it was.* Some utilitarian individuals blasted it; and part has been carted away; but three large portions remain. When whole, it must have been a most remarkable stone."

Notes by Mr. Ralph Richardson (a member of the Committee) of a Visit by him to Strathnairn, in the Autumn of 1881.

I drove last August (1881) from Inverness *via* Druids Temple and General Wade's military road, to Strathnairn, crossing the River Nairn at Daviot, and proceeding down its right bank to the celebrated "*Tom Riach*" boulder, returning *via* Clava and Culloden Moor,—a distance of about 20 miles. Shortly after passing Craggie Burn, Strathnairn, I was struck with the number of boulders dotting eminences throughout the valley, and with the depth of sand which covered the hills,—the whole pointing to a period of submergence in Post-Pliocene times.

To make this still more evident, I may cite the interesting discovery last summer by Mr. James Fraser, C.E., Inverness, of Arctic marine shells at the height of 500 feet above the sea, at Drummore of Clava in this district, being the second highest discovery of the kind made in Scotland. Several of the shells discovered here being now only found in Arctic regions, the sea which once covered this district must have been of a decidedly glacial type.

I examined the section at Drummore, and found that it exhibited a considerable depth of sand, beneath which the shells occurred in a bed of blue clay. Similar shells in similar blue clay are found near the sea coast at Ardersier, Fort George, about 8 miles due north from Drummore of Clava, and at an elevation of about 50 feet. It is evident from the occurrence of these shells in two separate localities, that this part of Scotland had once been covered by a sea of a temperature similar to that now washing the coasts of Arctic America, Finmark, and Spitzbergen. I also inspected the two famous boulders of the district, both of them huge conglomerate blocks, "*Tom Riach*" (the stone of the grey hill), measuring 27 feet × 22 feet × 15 feet, near Croygorstan, and the "*Duke of Cumberland's stone*" on Culloden Moor.* Probably neither of these are far travelled, conglomerate rocks being found *in situ* in proximity to them. The valuable papers by Messrs. Thomas D. Wallace and James Fraser of Inverness, in volumes III. and IV. of the *Edinburgh Geological Society's Transactions*, treat fully of the Boulder phenomena and geology of this interesting district.

List of Boulders in the Neighbourhood of Inverness, sent by Mr. Wallace, High School, Inverness.

1. Split conglomerate boulder, in the burn below Mid-Lairg Farm, in Upper Strathnairn.

2. *Clach-a-nid* (stone of the nest) lies on the N.E. shoulder of Meal-Mor, a hill 1207 feet high. The boulder is 950 feet above sea-level. It is composed of gneiss, and measures 28 × 24 × 14 feet.

3. *Brownie Stone.* A very large conglomerate boulder lying on the moor, half a mile north of Bunachton.

4. *Clach-na-h-ulaidh* (stone of the hidden treasure). A large block of gneiss, 12 × 12 × 5 feet, resting on the brink of a cliff of old red sandstone, overhanging the east bank of the Nairn River, a few yards from Nairnside House. It is about 40 feet above the river, and 400 feet above sea-level.

5. Gneiss boulder, measuring 6 × 5 × 4 feet, much rounded, lies

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* The "*Tom Riach*" boulder is between 300 and 400 feet above the sea-level; and the "Cumberland stone" is 487 feet above the sea.

on limestone, interbedded with the old red sandstone, at Dalroy, on the Nairn. It is composed of ordinary gneiss.

6. Conglomerate boulder in a field, a little to the N.E. of "Tom Riach" boulder, measures 95 feet in circumference, and 35 feet in length. It lies about 350 feet above sea-level. Same kind of conglomerate as the "Tom Riach," which would show that it came from the S.W.

7. Conglomerate boulder (same as other), lies in the bed of the River Nairn, to the East of Daviot House. Measures about 6 × 7 × 8 feet.

8. Four conglomerate boulders, same as last, on the moor, north of Nairnside School House, at a height of 590 feet above sea-level. One measures 14 × 8 feet, one 13 × 15 feet, one 9 × 9 feet, and one 9 × 8 feet. These may have come from west. They do not rest one upon the other.

9. In Cran-More Wood, Nairnside, there is one boulder measuring 9 × 6 × 3 feet, which is stratified conglomerate, similar to that found at Failie, about 5 miles to the west. This boulder lies at a height of 600 feet above sea-level. In the same wood there is a gneiss boulder, 5 × 6 feet, slightly rounded, and resting on old red sandstone.

10. Conglomerate boulder, on south shore of Loch Duntilchaig, opposite Achnabat, a few feet above the loch and 720 feet above sea-level. It measures 4 × 5 × 3 feet. There are several others of the same rock lying along the shore of the loch. These can easily be identified with the rock on Dunchae, which is about a mile to the W. There is no other similar rock in the whole neighbourhood. It is composed not of rounded pebbles, but of thin pieces of rock.

11. Granite boulder on the west shoulder of Dalcromlin Hill, which lies S.W. by S. of Inverness. This boulder rests on conglomerate rock, 1200 feet above sea-level, and measures 5 × 3 × 3 feet.

12. *Clach-an-abau* is a conglomerate boulder, lying in Petty Bay, to the E. of Inverness. It was moved by the tide. The waters round it had frozen, and thus served as a means of floating it. It is not large, perhaps about 4 × 3 feet. The underlying rock is old red sandstone.

13. Boulder of *Dirrymore* granite lies on the shore, a few feet above sea-level, to the E. of Kessock Ferry. *Dirrymore* lies N.W. by N. from Inverness. Boulders of this granite are found scattered over the shores of the Moray Firth as far east as Buckie. This boulder is lying on the gravel of the shore.

14. There are two boulders in Findhorn Bay; one of granite, measuring 4 × 3 × 3 feet, and the other of gneiss, measuring 5 × 3 × 3 feet.

15. The little burn to the west of Inches House, about 2½ miles S. of Inverness, is full of boulders. One interesting group of three may be mentioned. They lie one against the other. The one to the west is granite and measures 7 × 4 × 2 feet. The one in the middle is old red conglomerate and measures 6 × 3 feet. The one to the east is gneiss and measures 3 × 2 feet. They lie at a height of 200 feet above the sea-level.

16. There is a fine specimen of a striated stone, fixed in boulder clay, in the burn below Muckovie Quarry, about 3 miles S. of Inverness. The striæ when seen by me, when the stone was fixed in the clay on the bank of the stream, ran E. and W. It has now fallen from its original position.

17. *Porphyry Boulder.*—In wandering over Strathnairn and the district to the S.E. of Inverness, I was puzzled to know where the numerous specimens of porphyry could come from. While pursuing my investigation in the upper part of the Strath, I found the rock *in situ* between Loch Ruthven and Loch Duntilchaig. I have also, since that time, seen the same rock in other two places in Strathnairn, nearer the mouth of the river.

18. *Boulders of hornblende* are to be seen lying along the shore between Inverness and Culloden Station, as well as along the west shores of Loch Ness. There are two places on the west shore of Loch Ness, where hornblende rock is *in situ*. One of these, about two miles to the west of Loch End Inn, has been known to me for a number of years. The other, which is about two miles further to to the west, was pointed out to me by Dr. Aitken, Medical Superintendent of the Inverness District Asylum, who discovered it.

19. One of the stones in the so-called Druidical circles at Stoneyfield, about one and a half miles E. of Inverness, is quite unlike anything I have seen within a radius of 20 miles of Inverness. I

have not been able exactly to identify this rock, but from descriptions in mineralogical books, I am of opinion that it is a diorite. The stone has every appearance of being waterworn and rounded, but whence it came I cannot say.

20. One of the stones in the "circle" at Culloden Railway Station is a serpentine. There is serpentine in Glenurquhart, which is about 12 or 14 miles W. from Inverness. I do not think the builders of these circles would have gone so far for building material.

21. A friend of mine in Glenurquhart tells me that there are granite boulders in that district, differing from all the granites surrounding the Glen. He is investigating the matter, and I expect to have exact information regarding them soon.

Extracts by Convener from Notes supplied by Mr. William Morrison, Secretary to Field Naturalists' Club, Dingwall, Ross-shire.

1. On the south slope of Tulloch Hill, the following boulders occur:—

(1) At the height of 550 feet above sea, an irregularly rounded boulder of granite-gneiss, supposed to be one of those mentioned by Mr. John Campbell in *Frost and Fire*, vol. ii. p. 152, as consisting "of a peculiar kind of pink granite, resting on slate," and of which he gives a diagram at page 167.

Its girth is 29 feet; greatest length 11 feet; height 7 feet, and breadth 7 feet. Its major axis is N.N.W. and S.S.E., with sharpest end to E. The felspar in the boulder is pale red, and the mica so arranged as to produce a laminated appearance.

(2) About a quarter of a mile S.W. of No. 1, on Upper Docharty Farm, at 400 feet above sea, another boulder of same rock 8 × 5 × 5 feet; and major axis N.N.W. and S.S.E., with sharp end to west.

(3) To N.W. of No. 1 boulder, at a height of 620 feet above sea, a flat block of mica schist, 11 × 7 × 2 feet; major axis W. and E. The west end pointed, and appears as if scoured by running water.

The upper surface is scored by natural ruts, grooves, or striæ, 2 and 3 inches broad, and from $\frac{1}{8}$ to $\frac{1}{4}$ inch deep. These run in a direction from N.W. to S.E., and cross nearly at right angles the lines of lamination of the stone.

Over the upper surface of the boulder, there are about thirty-six *artificial* "*cup markings.*" These marks are faint, where scorings are deepest and most frequent. The cup marks are well defined at the N.E. end of the upper surface of stone, and also at the S.W. end. One seen well marked at S.E. side, about half an inch from top surface.

(4) On Drynie Farm, S.W. of No. 3, at height of 600 feet above sea, a mica schist boulder 12 × 8 × 4 feet; major axis N.N.W. and S.S.E.

On the surface of boulder there are six striations or groovings (not artificial), running N. and S.

There is one cup mark at south end.

(5) On Tulloch Hill, at 900 feet above sea, a boulder of same rock as No. 1 and 2, 8 × 6 × 4 feet, with major axis N.W. and S.E.

The prevailing rock on Tulloch Hill is a bluish grey indurated sandstone shale.

Where the outcrop stands upon opposite side of valley, the strata (dipping south at angle of 45°) have been rubbed and smoothed on their north faces by some natural agency, in many lines bearing N.W. and S.E.

The prevailing soil on Tulloch Hill is a pale reddish till, derived possibly from the rocks of red sandstone and conglomerate, which exist towards the west.

To the north of Tulloch Hill a moor stretches to a uniform height of 1100 feet, on which are many smaller boulders similar to those on the southern slope of the hill. They occur also to the east of the hill, all the way down to the Cromarty Firth; and (as reported) even to the Black Isle. In most cases of the boulders having one axis longer than the other, the direction of the former is E. and W.

2. Thinking it probable that these Tulloch Hill boulders came from the westward, Mr. Morrison states that he lately set out, accompanied by a few friends, on an excursion in that direction.

At *Garve* (about eleven miles west of Dingwall), rock was found with surfaces rounded, smoothed, and striated; the striæ running E. and W.

The Strathgarve district is covered with multitudes of boulders of granite and mica slate, chiefly the former. For miles along the Ullapool Road on to *Inchbae*, there are *torrents* of such blocks.

At *Achnaclerach*, there is a gigantic mass of the same kind of granite as the Tulloch Boulders, 25 × 23 × 12 feet above ground, about seventy feet in girth, and weighing probably about seven hundred tons; evidently an erratic, the kind of granite composing it being different from the rock on which it rests.

Farther along the road towards *Inchbae*, several other boulders of the same kind, and not much less in size, were seen.

At *Inchbae Lodge*, the ground is much covered by these boulders.

At the confluence of the rivers *Glascarnoch* and *Strathvaich* near the schoolhouse, rock appears *in situ* identically the same as that of the Tulloch Hill boulders. The felspar of the rock has the same pink colour, and the mica is segregated in bands. The bed of Strathvauk river is entirely composed of the rock, and it appears to break naturally into huge cubical masses, among which the river rushes and foams violently.

In proceeding further west no boulders were to be seen. We seemed to have at length reached the parent rocks; for to the N. of *Garbad*, a place about a mile S.E. of Inchbae Lodge, no more boulders were met with.

The boulders in this district occupy the valley, through which the *Blackwater* River flows.

The *schoolhouse* above mentioned (about seven hundred feet above sea-level) is at or near the base of a hill called *Druim Buidhe*, 1080 feet above sea, which presents naked cliffs of granite rock facing W.N.W.

"We examined the pass of the Bealach, situated between *Big Wyvis* and *Little Wyvis*, which reaches to a height of about 1250 feet, and runs in a direction N.W. and S.E., to see if any granite or other boulders were lying there; but we found no travelled blocks. The Bealach itself is full of gigantic blocks of mica schist detached from the side of the pass."

"It appeared to us, therefore, that the *Tulloch Hill* boulders had made a detour eastwards over the south shoulder of *Little Wyvis*, a hill which reaches to a height of 2497 feet. On the south side of the Blackwater Valley, the hills rise to the height of 1500 feet above the sea."

Of course it is most improbable that the boulders on Tulloch Hill, at a height of about 1000 feet above the sea, could have been derived from the rocks forming the channel of the Black Water, at a height of only 500 feet above the sea. The parent rocks must have been at an elevation above that of the boulders. It only remains therefore to examine the adjoining hills, exceeding 1000 feet in height, to see whether they contain granite rocks of the same variety, or in the channel of the Black Water at Inchbae.

"I found granite boulders in large numbers, and of huge size, in the bed and on the banks of *Alt nan Cuirach*, four miles west of Tulloch Hill, and on move to E. conglomerate ridge, ending at *Cioch Mhor*. The river has washed out many of these boulders from the base of scaurs of yellow boulder clay of a depth of from 40 to 60 feet. These boulders were traced at heights from 1000 to 1200 feet above the sea from river bed at a spot due S. from Loch Glass. They probably came from Carn-Cuineag, through the opening occupied by Loch Glass. Both *Alt nan Carioch* and the river *Glass*, of which the former is a tributary, cut all the way down to Evanton through deep cliffs of boulder clay, resting on hard sandstone strata dipping S.E. The granite boulders are imbedded at the very base of the clay deposits."

[The Convener being struck with the account given of the striæ and cup marks on Boulder No. 3, wrote to Mr. Morrison, to ask whether any idea existed in his mind as to the possibility of the striæ having been formed after the cup marks had been formed. His answer, dated 24th April 1882, is—"The suggestion forced on the mind unquestionably is, that the cups were partially obliterated by the scoring agent, and hence were made before the natural striæ."

If this suggestion is supported by further examination and study, it would indeed be a very marvellous discovery.

As Mr. John Campbell, in his *Frost and Fire*, refers to this district, the Convener gives the following extracts from his work :—

Page 149.—"Above the Inn at Garve, at about 600 feet, grooves on a rib of white quartz, turn with the glen. They do not point at Wyvis, or up into Strath Bran. They coast round a hillside, carefully avoiding the high hills, as rivers do at a lower level. They point S. 45° E.

"At the end of Loch Garve, beside the road, grooves on contorted gneiss take another turn with the glen. At about 150 feet above the sea, the marks point N. 70° E., and aim at the shoulder of Wyvis, which bars the way. On this hill side are piles of drift.

"If Strath Bran held a glacier which flowed N. and E. towards Ben Wyvis, stones left by it ought to be blocks of white and grey quartz and gneiss, fragments of rocks in Strath Bran and near it. But there is no such collection of native drift here."

Page 153.—"At 1000 feet up the side of Wyvis, the rock is laid bare in a small burn. It is a soft slate, dipping 10° south."

"There are blocks of granite on the hill, and a moraine in the glen. But the granite is foreign.

"At 1650 feet is a conical hill *Cloch Mor*,—a lump of hard coarse conglomerate. The sides are scored, the steepest end is down stream towards the west. In the supposed "*ice*" are large blocks of mica schist, bits of grey quartz rock, and a big boulder of gneiss.

"At 3000 feet, the ground on a shoulder of Wyvis is smooth and flat, the rock shows in the edge of a deep corrie. It is a coarse gritty sandstone, which splits into thin flags. On this high shoulder are blocks of gneiss."

Page 255.—"At 3000 feet on Beinn Wyvis, mica schist (boulders lie) upon slate."]

In company with Mr. MacLean, factor for Ardross, Dr. Sutherland, Invergordon, and Mr. Joass, Dingwall, I visited Carn-Cuinneag (2744 feet) in Ardross. The hill has two peaks, from each of which enormous shoots of granite blocks have fallen, many of which weigh about 400 tons. In Strath Ruasdale we saw on roadside a block of granite 22 × 21 × 12 feet. Major axis N.W. and S.E., and weighing about 462 tons. We observed to the W. on the sky-line on the ridge forming west flank of *Glac-an-t-Seilich*, at 1600 feet above sea, a huge cubical block. Further to the W. on the sky-line, on ridge close by north end of Loch Glass, is to be seen an immense erratic block, cubical, said to be the largest in Ross-shire. Carn-Bhren to N.E. of Cuinneag, reported to be granite. These two hills of granite are probably part of the same belt, which to S.W. crops up at Strathvaich. The country to S.E. of this belt is full of boulders, chiefly granite. Many hills on their N.W. faces denuded and sown over with blocks.

The gravel of the road from Ardross to Diebidale is granitic. We observed under banks, washed by streams, beds of till yellowish red. The felspar of the Diebidale granite is generally paler than that of the Strathvaich granite, but many blocks were found, in which the felspar had same pale red appearance. The hill, Carn-Cuinneag, is entirely composed of granite. The saddle between the two peaks appears like a shingly beach; rounded stones of about 10 lbs. weight are seen packed on edge here and there in crevices, with longer axis of stones lying all in same direction. The east peak has shot down its fractured masses on the N.E. slope, whereas the west peak has sent its broken masses down on the N.W. side. Carn-an-Lochan (2000 feet) to N.E. of Carn-Cuinneag is also a hill of granite. Carn-Cuinneag being the highest hill in Easter Ross, commands a magnificent panoramic view of hills and deep glens to the N. and E., and hills rising on wide moors to S. and W. Many of these latter are rounded or dome-shaped and much denuded, hence the Gaelic name for such (" Creachan "), as may be seen by Ordnance Map, is frequent.

It was suggested that Carn-Bhren, said to be granite, Carn-an-Lochan, Carn-Cuinneag, all nearly in line N.E. to S.W., were but prominences in a belt of granite running S.W. to Strathvaich. To determine that point is to be our next work.

The road up Strath Ruasdale, and on through *Glac-an-t-Seilich* (Gaelic Glen of Willows—none, however, there now), passes through numbers of boulders chiefly on the north side of the road, and resting on slope of the valley. Many of them evidently were carried from Carn-Cuinneag without losing much of their angular form, others had their angles well rubbed off by the grinding action of some heavy agency passing over them. These rocks were probably rounded by their fellow boulders, for where accumulations of these boulders appear largest, granite gravel and sand are associated with them, indicating that these huge blocks struck against each other, and that the hammering and grinding produced the gravel and sand found in their neighbourhood.

The prevailing rock passed over on way to Carn-Cuinneag is quartzite, of hard, compact, and flaggy structure, some of it is flecked by ferric oxide. Indeed, in Strath Ruasdale is found so large a quantity of good hematite, that a Birmingham firm offered Ardross £2000 a year for the mining of one huge rock. Another kind of rock prevailing to N. of Cuinneag is a hard blueish-grey quartzite (?), with a slabby structure.

Boulders were seen in the distance, perched on the sky-line of ridges to the west, of from 1600 to 2000 feet above sea.

W. Morrison,
Secretary to Ross-shire Field Club.

Mr. Morrison, in sending the foregoing notes, writes to the Convener a letter (dated 8th May 1882) from which the following extracts are given, as they supply information of interest:—

"Carn-Cuinneag, in company with Mr. MacLean, factor for Ardross, Dr. Sutherland, Invergordon, and Mr. Joass, Dingwall, I visited on Saturday last. The weather unfortunately was extremely unpleasant; sleet and snow with driving mists prevented more thorough work being done. However, we satisfied ourselves as to the parent source of most of the travelled boulders in Easter Ross. Carn-Cuinneag and its lesser neighbours, Carn-Maine and Carn-an-Lochan, we saw were granitic. Carn-Bhren to the N.E., the keepers told us, is composed of the same rock as Cuinneag.

"The rock of the hills to the N. in the immediate proximity of Cuinneag was found to be of a flaggy or slabby structure. Under the microscope it shows grains of quartz. The appearance of the rock is uncommonly like limestone, but the acid test (hydrochloric) decided it was not limestone. I am not enough of a geologist to determine what this rock is. The description given in Rutley's *Petrology of Quartz-Trachyte* answers well to what I found the rock to be under the microscope. Carn-Cuinneag is a remarkable hill. Its two lugs (hence the Gaelic name) are pinnacles of granite; the slopes descending from these peaks are covered with immense numbers of huge oblong blocks to within a short distance of the base of the hill. On the N. and W. slopes are to be seen shoots of stones of all sizes besides.

"Kildermore to the S.E. is strewn over with boulders, evidently from the Diebidale hills.

"I shall report result of our investigation of the hypothetical belt, extending from Carn-Bhren over Carn-Cuinneag and on to Inchbae, where the granite or gneiss was found *in situ* at Druim Buidhe as reported before, when we get to work.

"The granite of Carn-Cuinneag, in the main, is like that of Inchbae. We saw blocks of pure granite of the Peterhead pattern on the slopes of Cuinneag, but the granite characteristic of this district is that which I have described in my previous reports. The summit of Carn-Cuinneag must have been splintered by some terrific agency, to account for the overthrow of such gigantic masses as are found on both sides (N.W. and S.E. sides) of the hill. The blocks descend in perfect cataracts on both these sides.

"If we had an experienced geologist with us, it would add very much to our pleasure in exploring these regions; but in lack of one queries from you for further information will do much to direct our observations.—Faithfully yours,

"WM. MORRISON."

Extracts from a Memoir by Professor Duns of the New College, Edinburgh (a member of the Committee), on the Surface Geology of Mid Lochaber, read in the Royal Society of Edinburgh on 6th February 1882.

"*Boulders forming heaps or clusters* are met with in the low grounds and also high up the sides of the mountains. Those in the low grounds contain sand and gravel; while in the heaps on the heights there are boulders alone. The explanation most likely is, that those in the upland slopes have had the sand and gravel washed away by heavy rains.

A typical boulder heap occurs near the foot of the S.W. slope of "*Meall an t' Suidhe*,"* on the farm of Ashantee. So far as examined, all the blocks composing it differ from the mica schist rock on which they lie. They consist of different sorts, as granites and porphyries. The blocks near the heap are also granites and porphyries. One is of immense size, 13 × 12 × 6 feet. A large piece has been broken off, in the line of cleavage, by another large boulder which had fallen against it, and been pushed partially over the part thus separated. To the N.W. of this heap, are other great clusters, which look like little hills.

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* In English, "The hill for sitting on," in reference to the practice of travellers to the top of Ben Nevis resting on it.

The granites here are of various kinds, and frequently form boulders of great size. Some bear a close resemblance to the light red-coloured granite of Aberiachan, near Loch Ness.

Several of the heaps have a covering of peat. They lie in the course of a long line of single boulders referred to below.

Some large blocks are met with in association with many much smaller. Thus opposite to Lochy Bridge, at a height of 1500 feet, there is a porphyry boulder 7 × 6 × 5 feet. The rest of the heap is made up of small granite blocks.

Not far from this heap, there are several boulders lying in line to the N.W. * * * *

Boulders which occur singly.

Near the old military road between Fort William and Stirling which leaves the drove road at the S.W. end of the former, there is a large boulder near the top of a hill, about 400 feet above the sea, and looking down on Loch Linnhe. Standing by this great stone, and looking to the N.E. in the direction of "*Meall an t' Suidhe*," one sees a series of boulders in line in the same direction, though the line is not so well marked as in some other cases. The boulder is a coarse grey granite, that next to it in the line is a fine felstone. Two others are quartzites, the rest are mainly of the rock of the hill,—mica schist—much rubbed and rounded. On the east of the road again, is a boulder of a fine-grained pinkish granite, with a close resemblance to the Aberiachan granite. * * * *

Coming now to the area lying N. of the River Nevis, including both low grounds and mountain slopes, granite, granitic porphyry, and porphyry blocks lie for the most part in a line of their own, while schists, micaceous gneiss, and some porphyrites, lie in either side of them.

The mica schists are nearest to the mountain; the granites and porphyries next, and the others lie between them and the River Nevis.

The line is a diagonal of the area referred to, running in a N.W. direction.

Looking from near Claggan Cottage along the steep slopes of *Meall an t' Suidhe*, granite boulders are seen lying on the mica schist rocks, where the side of the mountain slopes down so steeply as to make it a puzzle to understand how they can remain in position.

Some on the lowermost slopes and in the plain are of great size, and present distinct marks of polishing and well-defined striæ;—viz., (*a*) Syenite, 17 × 5 × 6 feet, larger axis N.N.W. and S.S.E., with a deep conchoidal hollow at the broad end; (*b*) micaceous gneiss, 15 × 9 × 6 feet; two other large boulders of the same mineral lie in front of this, one to the N.W., the other to the S.W. of the line.

On the north aspect of one of these blocks, are several round hollows, so very like the cup markings of the archæologist, that at first sight they seemed artificial; but in another block, a bit, having been noticed protruding from the surface, on being struck with the hammer, fell out, leaving the cup marking on the stone; (*c*) micaceous gneiss, 11 × 7 × 7 feet; (*d*) mica schist (the rock *in situ*), 11 × 7 feet. * * * *

Slopes of Meall an t' Suidhe, from 100 up to 1500 feet.—On these, the size of the boulders and their "lie" to the horizon varies. (*a*) Porphyry, 7 × 5 × 4 feet, angle of its site to horizon 35°, longer axis N.N.W. and S.S.E. This boulder is poised on an edge, which towards the mountain is 1 foot 7 inches broad, and towards the plain only 5 inches. (*b*) Porphyry (triangular shaped), 9 × 7 × 5 feet, apex towards the hill, as if the point of the boulder had been violently driven into it, larger axis N.N.W. and S.S.E. On west side, a cup and ring mark. These oval or round marks are numerous, and occur chiefly on the N.W. side of the boulders;—angle of site to horizon 20°. (*c*) Micaceous gneiss, 13 × 8 × 13 feet, angle to horizon 20°. The heavy end rests on the mountain. At the point which stands out from the face of the hill; the depth is only 3½ feet; it lies mainly on three small rounded granite boulders, and is so poised as to suggest, that the slightest push would send it down the hill.

* * * *

At a point 1060 feet above the sea-level, a considerable part of the surface has been laid bare, and the rock is distinctly striated, the direction of the striæ being apparently N.W. and S.W., but partly obliterated by cross-hatching. * * * *

On the area to the N. of the rounded crest above Suidhe lake, and to the W. of the great corrie between Ben Nevis and Carn Dearg, there is, (*a*) an enormous boulder of mica schist, lying on porphyry *in situ*; (*b*) large block of grey granite; (*c*) large block of porphyry.

These lie in a mass, associated with smaller boulders of mica schists, and stretching from this heap are two rows of boulders lying nearly direct W. The first block is grey granite, 7 × 4 × 6 feet, angle of site to horizon 40°; the others are grey granites, porphyries, and mica schists, their larger axis being N.N.W. and S.S.E.

The most noticeable feature is the "lie" of these blocks to the hills; they appear in long lines sometimes far apart, but there is no mistaking their place in the lines, which are W.N.W. and E.S.E. The larger axis varies so much, that from it no inference can be drawn."

Towards the conclusion of his paper, Professor Duns remarks that the gravels of the district consist mainly of rolled and water-worn fragments of granite, porphyry, quartz, mica schist, bits of arenaceous rock, and at one part of a mineral (malacolite) nowhere found massive in the locality. In the rare instances in which large boulders are met with *in* these gravel heaps, they are sub-angular blocks of the rocks of the immediate neighbourhood. The *erratics* occur *on* the heaps.

"On nearly all the mountain slopes, and even at the tops of some, blocks abound; many of enormous size and weight, for whose positions no explanation can be found in any of the forces at present existing in the locality.

The position of boulders in the plain may have as great significance as the position of those high up on the mountain. Thus, if a granite erratic be found at a height of 1000 feet, and one of the same rock in the low ground, at a height of 50 feet above the sea-level, in a place to which it could not have rolled, assuming the face of the country to have been the same as now, when the boulder on the high level was laid down, it will follow, either that one and the same force put them contemporaneously in their respective positions, or that the valleys, river courses, and little hills which now intervene between the high and the low blocks were formed since both were deposited. There is only one other alternative. Each may have been dropped by an agent, on which inequalities of surface could have no bearing.

A careful examination of the deposits within the area described, so far as they bear on Arctic conditions of climate and a glacial surface, leads to the belief that the bulk of the phenomena may ultimately find their explanation in the recognition of two movements,—one outwards from Ben Nevis as a centre, the other a force travelling from the W. the N.W. or the N.N.W."

Extracts by the Convener from Notes on Boulders and Striated Rocks situated to the W. of Fort William, by Colin Livingston, Teacher of Public School, Fort William.

The places mentioned by Mr. Livingston (Plate V.) are shown on the map reduced from the Ordnance Survey.

1. *Meall nan Cleireach*,* the height of which above the sea is 1651 feet, composed mostly of micaceous gneiss and clay slate. About 60 feet below the summit, is a boulder called "*Clach an Acrais*"† or the "Hunger stone" 8½ × 6 × 3½ feet. Its longer axis is N. 5° W., with heavy end to north, resting on clay slate. It bears from the summit of the hill N. 10° E. It might have come to its present position through Glen Nevis, or Glen More, or (but less probably) Glen Scaddle, on the W. side of Loch Linnhe.

A second boulder, 17 × 6 × 3 feet, lies N.E. of the former at a distance of 24 yards. Its axis is N. 8° W., and about 70 feet below summit level of hill.

Both of these boulders are of mica schist with garnets. A third boulder 15 × 7 × 6½ feet to the E. of the first mentioned, and distant about 40 yards, is mica schist without garnets.

These three boulders, being in sight of and near each other, are spoken of by Mr. Livingston as forming a triangle.

Mica schist with garnets is a rock not known in the neighbourhood. Dr. Heddle found it *in situ* on *Aonach Beg*, a hill to the E. of Ben Nevis, about 4060 feet above the sea, where it is open to Glen Spean and Glen More.

2. Other boulders with garnets occur at the following places:—

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* Mr. Livingston explains that this word means "Hill of Clerks or Clergy," implying that it belonged to the church.

† When the people at "Blar-mach-foldach" saw the sun over this boulder, viz., at 2 P.M., they went to dinner.

(1) A large mass about 200 yards above where the road from Fort William crosses the river *Abhainn Bheag*, 18 × 10 × 7 feet.

(2) A similar block 11 × 7 × 5 feet at a short distance.

A line connecting these bears almost on *Clach an Acrais* boulder.

(3) A small boulder nearly in same line about a mile from Fort William to the W.

(4) At nearly same distance from Fort William on the E. side of the town a similar boulder of larger size on the hill face above Nevis Bridge.

If a glacier came down *Glen Spean* and along *Glen More* it might have brought the above boulders.

The idea of such a glacier is favoured by the existence of a remarkable *trainee* of boulders to the E. of *Blar-mach-foldach*,* partly above road on left, and partly on right at first house in township.

3. A more striking indication of ice movement in this direction is an immense collection of boulders on lower slopes of same hill, *Meall nan Cleireach*, called *Blar nan Cleireach.* The shoulder of the hill which projects so as to cause the bend of the river *Kiachnish*, is littered with boulders. The boulders are mostly granite. There are also boulders of porphyry and mica schist. The largest in size are mica schist.

Most of these boulders are below the contour line of 800 feet. The following are the sizes of the largest mica schist boulders: 10 × 8 × 5½ feet, 8 × 7 × 4 feet, 10 × 6 × 3 feet, 11 × 4 × 5½ feet, 7 × 5 × 3½ feet.

The granites are grey and purplish. The pink colour is owing to the predominance of felspar. In some, the felspar crystals are large, in some, small.

Of the boulders with large felspar crystals, one may be mentioned 10 × 8 × 3 feet, one with small felspar crystals 8 × 5 × 4 feet. Fine grained grey granite 4 × 2 × 5 feet. There is one called "agglomerate," 7 × 5 × 3 feet. Among this collection, there are one or two small quartzite boulders.

This large assemblage of boulders is on the N.E. shoulder of the hill. It could be reached by an arm of the Glen More glacier passing down over the col between *Achintore Hill* (940 feet) and *Bein Riabhach* (1300 feet), the watershed between which is from 400 to 450 feet, and by an arm of the Glen Nevis glacier through the transverse valley of the Riasgaig. *Achintore* hill has *striæ* N. and S. at 590 feet.

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* This Gaelic word means "Green spot, outlying, hospitable."

Mr. Livingston observes that the lower boulders could hardly have come from the westward, as the only opening in that direction is the channel of the river *Kiachnish.*[*] To have come by it would imply their having crossed the supposed ice stream of Glen More, here flowing along the bed of the present Loch Linnhe.

4. Showing that ice has moved in this direction from Glen Nevis, we have on a ridge separating that glen from the valley of the Riasgaig—a feeder of the Kiachnish—the remarkable boulder called *Clach a Sgrogaidh* or "The tilted Stone" (1790 feet), between the summit of *Sgor Chalum* and *Glas Chreag.* This boulder is 10½ × 6½ × 9½, axis W. 10° S. It is of compact mica schist, indurated, finely laminated with quartz veins, and contains chlorite and ilmenite. The rock on which it rests is of somewhat similar material, but differing considerably in structure, containing neither of the two latter minerals, which occur in Aonach Beg rock.

Within a few yards of it, and nearer the Glen Nevis edge of the ridge, is another boulder of the same kind of rock, 12 × 7 × 5 feet.

Above these, on the shoulder of *Glas Chreag*, at a height of 1930 feet, *striæ* occur, their direction being N. 20° W., apparently formed by an agent passing from Glen Nevis towards the glen of *Kiachnish.*

Proceeding further south along the skyline, a small angular perched block is seen at an elevation of 2170 feet, with its axis N. 25° E. It is quite angular, and might not have been carried far.

At about the same elevation, on the Kiachnish side of Glas Chreag, there are *ten* blocks all of considerable size, the two largest 7 × 7 × 4 feet, and 7 × 4 × 4 feet. They also are angular, and lie on the surface of detrital matter. They are open to *Glen More* and lower *Glen Nevis*, but more probably were brought from upper Glen Nevis by a glacier winding round the shoulder of the hill—Glas Chreag—through Glen Riasgaig.[†]

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[*] This word means "Stream from a marsh."

[†] *Note by Convener.*—It is difficult to understand how the supposed glacier could *wind round the shoulder* of the hill here referred to. The position of

5. In *Coire-a'-Mhiulinn*, farther round the shoulder of Glas Chreag, there is a large angular block 8 × $6\frac{1}{2}$ × 5 feet. The rock is mica schist, indurated and thick bedded. It rests on native rock—mica schist also, but much softer and more fissile. Rock identical with it is found at the head of *Coire Riabhach*, which looks in to Glen Nevis.

6. Another feature of the locality is that while there are few or no boulders on the W. side of *Meall a' Chaoruinn*,* they are very numerous on the E. side, which is open to Glen Nevis through the glen of the Riasgaig.

Another large boulder of indurated micaceous schist occurs at the foot of *Meall an-t-Snidhe*, on the opposite side of *Glen Nevis* near its mouth.

7. On the east side of the streams forming the Riasgaig, at an elevation of 600 feet and under, there are boulders of the following sizes: grey granite 8 × 6 × 3 feet, two granite boulders with pinkish felspar 15 × 9 × 9 feet and 10 × 6 × 5 feet, and smaller ones. They may have come from *Glen Nevis*, or *Glen More.*

8. Mr. Livingston, under the head of "General Conclusions," suggests that the boulders mentioned by him may have come by two glaciers, one descending Glen Nevis, the other Glen Spean and Glen More.

(1) With regard to the former, Mr. Livingston observes that from the confined nature of Glen Nevis in its upper part, and the height of the mountains enclosing it, the glacier would probably be of great depth, reaching to a high level. After passing the spur of Ben Nevis, opposite Achriabhach, the lower portion would turn to the right, but the upper and much larger portion would continue straight on, through *Glen Riasgaig* towards Linnhe Loch. Hence (he says) the accumulation of boulders upon *Blar nan Cleireach.*

As the boulders on *Meall nan Cleireach* are at a height of 1630 feet, *Clach a Sgrogaidh* at 1790, and *striæ* at 1930, the glacier must have reached at least 2000 feet.

Mr. Livingston observes that a portion of the Glen More glacier may

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the ten boulders on the surface of *detrital matter*, seems rather to suggest the agency of water and floating ice.

* This name means "*Hill of Rowan trees;*" though there are none there now.

have united with the Glen Nevis glacier, and added to the boulders upon *Blar nan Cleireach.* He says that the general character of the boulders brought by the two glaciers differed. Granites of various kinds were brought down by the left flank of the Glen More glacier, and by the right flank of the Glen Nevis glacier. Mixed with these granites are occasional blocks of mica schist with garnets.

The left flank of the Glen Nevis glacier, he says, seems to have brought mica schists of various degrees of hardness, in some cases passing almost into quartzite. With these is mixed an occasional small block of true quartzite from *Sgor a Mhaim* and *Stob Bàn.*

Occasional blocks of porphyry are also met with. One or two fragments of actinolite, which is found *in situ* above Glen Nevis House, may also indicate the course of the *Glen Nevis* glacier. They were found on the road near Blarmachfaoldach.

On the left of the river Nevis, above Glen Nevis House, innumerable blocks, mainly of mica schist, occur. They have probably come partly from *Coire Riabhach*, partly from the shoulder of Ben Nevis above *Achriabhach.*

At the entrance into Glen Nevis, on the E. slope of the *Cow Hill*, above a small burial-ground, the stream called *Allt Eas an l-Slinein* cuts through detrital matter consisting mainly of granite boulders. It has long formed quite a quarry for building stone. One large granite block, found on the opposite side of the Nevis, furnished stone for the whole front of the Belford Hospital, Fort William.

On the right of the lower Nevis also, towards Inverlochy and Torlundy, there are immense mounds and ridges of detrital matter, the material of which, Mr. Livingston says, has "an imperfect stratification"—"such as might be produced if it fell from some height." He therefore supposes that the detritus was brought down by surface streams on the Glen Nevis glacier, and by others flowing on to that of Glen More.

He says there are also "remarkable lines, undoubted moraines, occupying great part of the area stretching towards Spean Bridge. One of these begins at the foot of the hill on the left of the Lundy, and may be traced almost continuously to *Blàr Odhar*, a distance of eight or nine miles. The part near Glen Nevis appears to have been formed by a glacier moving up in the direction of the Spean, while the further part, and the three similar lines nearly parallel with it, have apparently been formed by a glacier descending the Spean valley."

Extracts from Notes sent to the Convener by Dr. Heddle, St. Andrews.

1. On descending the west slope of East Lomond Hill, Fife, at a height of 1075 feet, overhanging Greenwalls, found a large number of dolerite blocks, from 4 to 7 feet in length, much rounded. They lay closely together on the brow of "a fall-over of the ground to the west."

About 40 vertical feet from the highest, and 20 from the lowest of the boulders, and at a distance of about 200 yards, a quarry of the same kind of dolerite was met with, in jointed pillars—the joints being somewhat open or loose.

"Concluded, that ice, sweeping from the west," had struck the west slope of the hill, where the dolerite rocks protruded, and pushed before it some of the loose pillars.

2. On descending Auchluisky Hill (one of the Ochils), into Glenquay, at a height of 1025 feet, found a small red granite boulder weighing about half a cwt. The slope on which it lay faced W.N.W.

On ascending Benty Knowe, directly opposite, at height of 905 feet, found another red granite boulder, rather smaller. The rocks of the Ochils here are trap,—a "rotting clinkstone."

3. On ascending Bencleuch from the east, at a height of 2200 feet, found two boulders, each weighing about 4 tons, in a line with each other E. and W. One of the boulders is a variety of greywacke, which may be called "almond conglomerate," from its containing nodules of white quartz of the shape of almonds, but two to four times larger. Recognised the rock of this boulder to be the same as a rock at the foot of the north spur of Ben Lomond, mentioned in last year's Report, page 28, at a height of from 2230 to 2240 feet above the sea. The Rev. Mr. Peyton (who has frequently accompanied Professor Heddle in his excursions, and is a good geologist) mentioned having seen the same rock *in situ*, about 8 miles to the east of Ben Lomond.

The other boulder was of gneiss, laminated and convoluted in structure;—much resembling rocks *in situ* in the district of Loch Earn and Glen Falloch.

4. Walked in the Lewis from Stornoway to Tarbert, in Harris. The north part of the district, where not covered with peat, consists of glaciated rock, with ill-defined striæ running in almost every direction except N. and S. The general flatness is the more remarkable as the strata are nearly vertical, so that their edges have been ground down by some agent passing over them.

This flat district of course terminated on the south at the base of the Harris Hills. One or two of these reach a height of about 2600 feet, and glaciers were no doubt formed in some of their valleys; but the levelling of the district to the north cannot be attributed to them.

The trench between the two Lochs Tarbert, where, in the previous year's Report, boulders were reported to have been seen, was again visited. There is evidence here of two independent glaciations. "In the main trench, there is evidence of ice rising on the hill sides to a great height, as if squeezed up, when moving through the pass from the west." In Glen Skeaudle, again, which joins the main valley at an obtuse angle, there is evidence of a small glacier, which pressed seaward to the west.

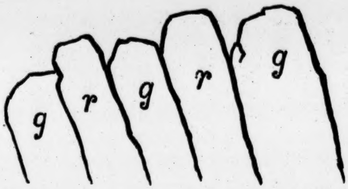
5. *Morvern.*—Walked for about ten days over the hills on the Glen Sanda property.

The shores of Loch Corry are much glaciated on both sides—in the same direction, namely towards the east.

A knoll or boss of red granite at the mouth of the loch attracts notice, from the way in which, on its W.N.W. side, the rocks on a slope reaching up to 150 feet were all rounded, smoothed, and scratched. The opposite, or S.E. side of the knoll, was rough and craggy.

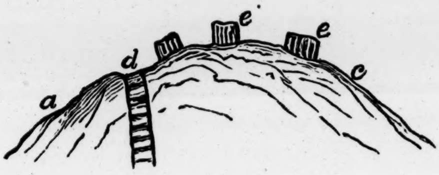
On the north shore of Loch Corry, near its mouth, an angular block 27 × 27 × 10 to 13 feet was observed; about 28 yards from it, a hollow in the rocks was discovered, which, in dimensions and shape, exactly fitted the boulder; this hollow was situated N.W. of the boulder. The boulder was about a foot lower in level than the hollow it came out from. A thick mass of floating ice was probably the transporting agent.

Several of the hills on this Glen Sanda property reach to a height of 1800 feet and more. They show glacial action to their very summits,—by the rounded surfaces of the rocks where hard. But at one place a series of grey granite and red granite strata were seen to alternate thus:—the strata marked *g*, representing the soft grey granites, formed as it were trenches between the red granite strata marked *r*. Most of the boulders on the hill slopes were grey granites.



6. From Stage House, on Loch Shiel, examined a valley leading to the west. Ascended double-peaked hill of Fraoch Bheinn, 2680 feet; on approaching each summit, found many blocks apparently torn from their natural beds, and carried very short distances eastward. In some of the belts of rock, sockets or hollows were observed, from which the blocks had been detached. These were from 20 to 40 feet below the east summit on its west side, and had manifestly been pushed up hill. These blocks weighed from about a ton to 10 tons. The top of the hill is pointed in a remarkable manner by a block of about 6 tons, "which is nearly turned up on end. It did not seem to have been moved more than a yard."

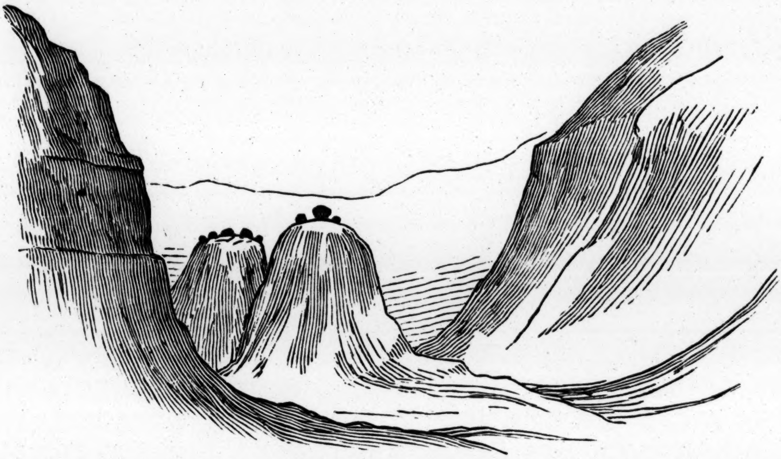
7. (1) *Fort-William District.*—In company with Mr. Livingston, went up Glen Finnan, at the head of Loch Shiel, then over a hill of 2419 feet (name unknown). Much glaciation in the col between it and the east top of Sgor-nan-Coireachan (2718 feet), a hill of gneiss. A great white granite vein or dyke cuts right through the col running N.N.E. and S.S.W. This dyke (8 to 10 feet thick) is a few feet below the summit-level of the col on the west side, thus:—*a e* being a transverse section of the col, *d* the granite dyke, and *e* blocks from the dyke, lying to the east of the dyke. The outcrop of the dyke was quite rounded; some of its blocks were found one-third of a mile to the east,—none to the west.



The summit of the hill (3136 feet) showed no glaciation. Ice, however, had gone over the col (2600 feet) between this hill, and that to the west (not named in the map).

From the 2500 feet contour line, to within almost 200 feet of the bottom of Glen Oban, there is one of the most tremendous scenes of glaciation probably to be seen in Scotland.

The sides of the glen abound in shallow corries, with large portions scooped out in some places, and smoothed over in others. There are precipices at many places rounded from top to bottom, some of them more than 100 feet in height. Local glaciers may have done the work.



Glen Oban, looking east.

The scooped-out parts of the Glen face the north, at right angles to the trench of Glen Oban.

The central parts of the Glen are nearly blocked by enormous masses of rock, fallen from a cliff on the north side, about 700 feet above.

At the mouth of Glen Oban, looking eastward, there are fine examples of perched blocks. These blocks in two cases rest on glaciated knolls or nobs of rock, situated in the centre of the Glen, as shown in the foregoing rough sketch. These knolls are from 300 to 400 feet high, and cannot be climbed, their sides being so steep.

(2) Walked from Fort William to top of *Ben a Gueaig* (2017 feet) (to connect the traverse of a former year) along ridge to *Meall na*

Cleireach (1626 feet). Found near Corunanan House several small boulders of the same syenitic granite, which I found last year in a *trainee* on the top ridge of *Stob Choire a Chearchaill* on the north side of Linnhe Loch (*Seventh Boulder Report*, p. 36), and on *Bein Bhan* on the south side of the loch. The felspar was not so red in these boulders; no other difference.

Found on south spur of *Meall nan Cleireach* a boulder, 4 × 6 × 4 feet, of a peculiar rock, which I learned afterwards had attracted much attention from Mr. Livingston and Professor Duns. The material of the boulder looks like a very vitreous hyaline quartz rock—the grains running into each other. The large amount of felspar in it, has cemented the grains of quartz. Many examples of this boulder were afterwards discovered. The parent rock I have never met with. I named it, for identification, after Mr. Livingston.

The ridge between *Bein na Gucaig* (2017 feet) and *Meall nan Cleireach* (1626 feet) consists of an igneous dyke, and is sprinkled with very small boulders, (1) of the red binary granite (felspar and quartz, almost a porphyry) of the hill *Mullach nan Coirean* (3077 feet) lying nearly due E., (2) of the above mentioned syenitic granite, (3) of the Livingston rock, (4) of a fine grained diorite, not found *in situ* by any of us, and (5) two small boulders of quartzite.

The top of *Meall na Cleireach* I found "intensely interesting." Three boulders lay on its N.W. side about 20 feet below summit. They lie about 50 feet above the three which are mentioned in Mr. Livingston's notes as forming the points of a triangle. The hill showed bare clay slate rocks on its W. side. Every other part had a thin cover of turf over it, and for about 50 feet down; from which point to the summit, but only on the N.E. side, there was a deep deposit of angular masses of rock, tossed in confusion as if rolled from off a glacier. They were thinly covered over with turf; but on clearing the turf off, the boulders were found to consist of micaceous gneiss and red granite.

On descending the hill towards the stream, and about 400 feet above it, I "came on a clump of three boulders." Two of these are of interest; one 13 × 4 × 4 feet being of *grey* granite with a little red felspar;—the other 5 × 3 × 2 feet, a mass of matted fibres of amianthus.* We afterwards found a similar rock (but far from identical) 3 miles N.E., near limestone, overhanging Glen Nevis.

(3) On following day, went up to *Mullach nan Coirean* (3077 feet). It forms a great round dome, all of red granite, tending to porphyry. On its summit there are several small angular blocks of pure white quartz rock, the nearest locality of which is the peak of *Stob Bhan ;* others had been built into the cairn.

The ridge from this hill to Stob Bhan (3274) is one of exceeding interest. It is narrow, falling and rising five times, forming so many little hills.

In the second of the depressions, at an altitude of 2904 feet, the rock is of red syenitic granite, apparently the same as that of the boulders before mentioned on Ben-a-Gucaig and Ben Bhan, and also as forming a trainee on *Stob Coire Chearchaill.*

We afterwards found the same rock in abundance near the great precipice of Ben Nevis, at an altitude of 2200 feet.†

At another part of the ridge, the ground falls from 3004 feet to 2904 feet; and there "for about 100 yards, the ridge consisted of a bank of loose material." Whether a glacier, which had been pouring through, or rather sending a delta-branch through the hollow, showered down the heaps of stones which form the ridge, or whether it had been deposited by aqueous agency, may be matter of opinion. By going down the S. slope, and by peering over the precipices of the next height, so as to see the N. slope, we inferred that this bank was about 40 feet deep. It was quite "like the patch on the N.E. top of *Meall nan Cleireach*; only, in addition to angular blocks, it contained much gravel and small rounded stones." Its ridge was broad enough for three persons to walk abreast. The heap is made up of many kinds of rock,—micaceous gneiss, Livingston rock, and quartzite being common. "I hope I have made it clear that the forementioned bank is the connecting ridge between the 3004 feet hill and the next hill (2995 feet). This last mentioned hill rises out of the bank in plumb precipices of say 30 to 60 feet,—a deep-red burnt-like porphyry, rudely columnar."

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* I found no other grey granite boulder on the S.W. of Nevis, though many on the N.E. The amianthus boulder may fairly be referred to the lime locality near Glen Nevis.

† This discovery of a rock *in situ*, identically the same as the rock composing boulders seen on Stob Coire a' Chearchaill, alters the opinion I had formed last year as to the direction from which these boulders had come.

Stob Bhan (3274 feet) and *Sgor a Mhaim* (3601 feet) are both of them quartzite; but the connecting ridge was found to be in some places almost a clay slate.

(4) On following day, drove up Glen Nevis to *Achriabhach*, and from that walked up past Steall, and thereafter climbed the quartzite ridge to the N.E. The first half of the walk astonished me on account of the absence of boulders, in this part of Glen Nevis,—considering the thousands which lie at and about the mouth of the Glen. Above the narrow part of the glen at *Meall Cumhann* (2000 feet) the whole surface seemed swept clean. We saw only one boulder (micaceous schist) about a yard square. It lay on the S. side of *Sgòr-a-Choinnich Beg* (3108 feet) at an elevation of 1830 feet. We went, in an easterly direction, over seven other hills from 3600 to 3858 feet in height, and then descended the N.W. slopes of *Stob Coire Chalourie* to *Corrie Coilzie.* Until we came near this last named place, we saw no boulders. Between the heights of 1740 and 1260 feet on the N.W. slope, we came upon eight boulders lying rudely in a line, "as if part of a lateral moraine." They were all much of one size, about 6 × 6 × 5 feet; and they were of two kinds of rock only, viz., the Livingston rock, and a grey granite rather fine in grain;—the site of neither rock is known to me.*

(5) Another excursion was made with Mr. Livingston to *Craig Dhubh*, a hill near the mouth of Glen Roy. We found a number of huge boulders at 1780 feet, and extending to within 20 feet of summit, (which is about 2200 feet above sea). They lay on S. and S.S.E. side of hill. There was well-marked glaciation, with much rounding of rock-surfaces at 2050 feet, in a line N.N.W. and S.S.E.; and it seemed to us that the movement had been from the last point, but we had not time to satisfy ourselves on the point. All the boulders seen on this hill are of the same two rocks as those seen above Coire Choilzie (*i.e.*, on the slopes of *Stob Coire Chalourie*, at the height of 1740 feet), over which we had passed two days previously.

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* Professor Duns having read these notes, informs the Convener that boulders of the kind of rock here mentioned (Livingston rock), were observed by him on the slopes of *Meall an t Suidhe*, near the mouth of Glen Nevis.

"This hill should be thoroughly explored." *

Professor Heddle in concluding his notes, states that—"Looking to what I saw on and of the ridge which forms the S. side of Glen Nevis;—the patch of matter on the N.E. side of the summit of *Meall nan Cleireach*;—the quartzite blocks on the summit of *Mullach nan Coirean*;—the red felspar syenite *in situ* to the E. of this;—a detrital bank at an altitude of 2904 feet;—and the quartzite and gneiss hills to the E.,—no doubt remains on my mind of there having been a glacier, which, sweeping down Glen Nevis, overtopped the hill of 3077 feet, on which, when decreasing in bulk, it may have left the quartz blocks; that when it dwindled somewhat more, it carried off blocks of the syenitic granite from somewhere near its 2904 feet locality; then, overflowing all the lesser heights to the W., crossing the Linnhe Loch, and sweeping into the directly opposing *Sroin a Chearcaill* glen, it was finally stopped by the precipice of *Stroin Coire Chobarceaill*, upon the ridge of which (2300 to 2500 feet) it left the boulders, as a kind of terminal moraine." "That while still further dwindling, it laid down the detrital patch on the N.E. top of *Meall au Cleireach* (1580 to 1626 feet). Lastly when its bulk was no longer great enough to pass in a direct westerly course over 1600 feet hills, it was deflected by them into the N.W. bend of Glen Nevis."

He is also of opinion that another great glacier, of nearly equal spread but lesser depth, may have been cradled in the gorges which lie between the lofty ridge of Aonach Beg and Aonach Mor, and the nearly equally lofty quartzite ridge which stretches from Sgor-Choinich Beg to Stob Coire Chalaurie;—and that this glacier may have sent a tongue of ice northwards across the scoop of Lochaber. Before committing himself, however, to such a view, he would require many more days exploration of the district.

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* [*Note by Convener.*—There is the greater reason for the more thorough exploration here suggested, because *Craig Dhu* has been examined by several other geologists,—Professor Nicol, Mr Jameson (Ellon), Mr Jolly (Inverness), and the Convener. The opinions formed by several of these, were that the agent which transported the boulders and glaciated the rocks on the hill came not from the eastward but from the westward. *Royal Society of Edinburgh Trans.*, vol. xxvii. p. 640.]

Remarks by Mr. Milne Home, on presenting Report, 5th June 1882.

As Convener of the Boulder Committee I now present the Eighth Annual Report.

I presume it is not expected that I am to read the Report, and that it will be sufficient if I describe verbally what appear to me the most interesting parts.

But before doing so, I beg to offer a few remarks of a general nature, explaining the objects for which the Committee was appointed, and the lines of inquiry pursued, as members will in this way be better able to see the bearings of the information contained in the Report.

These blocks of stone called boulders, so called probably from their generally rounded form, were first subjected to scientific observation and discussion, about seventy years ago, by a distinguished Fellow of this Society, whose portrait, as President, hangs on these walls—Sir James Hall of Dunglass. His Memoir on the subject was published in our *Transactions,* I think, about the year 1812. He was the first who realised the fact that most of these boulders, before reaching the sites now occupied by them, had travelled great distances; and having convinced himself, by a close study of the position of the boulders, that they had come from the westward, he suggested that there had been great inundations of the sea, whose waters swept fragments of rock across the country, subjecting them to enormous friction, and thus giving to them their rounded forms.

That theory was accepted for many years, until it was pointed out that boulders, similar in appearance to those in Scotland, and not less in magnitude, were to be seen travelling on the surface of glaciers, and, on reaching the lower extremities of these glaciers, were thrown down on localities remote from the rocks of which they were fragments. This view obtained great favour about the year 1840, having been advocated by the distinguished Swiss naturalist Agassiz, who, in company with the late Professor Buckland, visited the Highlands of Scotland, and declared that the transport of our Scotch boulders might be accounted for in that way.

At a later date, it became known that boulders, both numerous and large, were to be seen on icebergs and shore—ice floating in the Arctic Sea, and from which they were dropped when the icy rafts melted, or stranded on submarine rocks or sandbanks. To make this explanation possible for Great Britain, it implied the submergence of the land beneath the waters of an ocean many hundred feet above the present sea-level, and having a temperature greatly lower than that of our present British seas.

Whilst each of these theories has its supporters, all geologists are agreed on one point—that for the transport of our Scotch boulders, many being hundreds, some even thousands of tons in weight, in order to be carried many miles across a country, some agent of tremendous power has to be sought for, of whose existence and operations these boulders were witnesses. Could these boulders speak, what curious revelations would they not give out; or, could the mysterious markings on the surface of many of them, markings impressed whilst *in transitu*, be rightly interpreted, what important inferences as to the nature of the agent which carried them might not be obtained?

Another circumstance added to the interest of the inquiry. The events whose occurrence these boulders indicate must have been, in a geological sense, of recent occurrence. The boulders lie generally above all the rock-formations, and even above all the beds of clay, gravel, and sand, which form the surface of the country. They, therefore belong to a period subsequent to any of these geological deposits.

Such were some of the speculations current among geologists when, in the year 1871, this Society resolved to appoint a Committee to investigate the subject. Though our Society was, I believe, the first in Great Britain to take this step, other societies on the Continent had preceded us. Three years previously, Professor Favre of Geneva had organised a committee of inquiry for Switzerland, and at his instance the Geological Society of France took similar steps. I received several letters from the Professor, urging me to propose this inquiry also for Scotland. His communications having been made known to the Council of our Society, the result was the appointment of a Committee in April 1871.

In the autumn of that year, the British Association for the

Advancement of Science held its usual annual meeting, and it in like manner appointed a Boulder Committee for England.

For the first year or two of its existence, our Committee was occupied in procuring intelligence regarding boulders by circulars addressed to the parochial clergy and schoolmasters, and in our first two Reports, the information given was almost exclusively a statement merely of the localities of the boulders made known to us, their dimensions, and their altitude above sea-level. But latterly, the Committee, besides obtaining information on these points, has endeavoured to ascertain facts which seemed likely to throw light on the different theories of transport. Thus, almost the first question for eliciting information, in the event of the rock of a boulder differing in composition from all the rocks in the neighbourhood, was whether any other part of the country was known, where the same kind of rock prevailed? That being ascertained, How many miles must the boulder have travelled, to reach its site? In what direction by compass-bearings, did it travel? Had it to cross any valley *deeper* than its site? or to cross any range of hills *higher* than its site? or to cross any arm of the sea? If there were boulders perched on the summit or ridge of a hill at a great height, were there hills in the neighbourhood at a greater height, fit for being the birthplace of a glacier which might have brought the boulders?

These are examples of the inquiries which our Committee has latterly instituted, in order to obtain data for the solution of the problem. I by no means say or think that the data obtained are yet sufficient; but in the eight Reports supplied by the Committee, a large amount of information will be found which at all events clears up many points of interest.

I will now indicate verbally certain parts of the present year's Report.

During the past year materials have been contributed by twelve gentlemen, four of whom are members of the Committee.

1. The district regarding which most information has been obtained is a very important one. It is the district of which *Ben Nevis* is the highest point, and it comprises about 12 square miles. The *Ben* itself reaches to an altitude above the sea-level of 4406 feet; but within the limits of the district, there are many hills exceeding 2500 feet, and several exceeding 3000 feet.

The labour of climbing these hills to examine the boulders on them is much enhanced by proximity to the sea-level. Mountains in the interior of the country generally rise from an elevated plain, which, of course, lessens the ascent to their tops.

The boulders in this Ben Nevis district are described in notes by Professor Duns and Professor Heddle, two members of the Committee, and by Mr. Colin Livingston, teacher of Fort-William Public School.

Professor Heddle and Mr. Livingston having joined in the examination of the district, a map has been given to show the tracks followed by them; it also includes the localities mentioned in the notes by Professor Duns. (See Plate subjoined to Report.)

It will be seen from the notes by Professor Heddle and Mr. Livingston, that they think that most of the phenomena observed by them can best be explained by supposing that a glacier passed through Glen Nevis in a northerly and N.W. direction. It appears to the Convener that the facts most strongly favouring this view are the boulders, consisting of rocks (especially red syenite and quartz) identical in composition with rocks forming hills situated to the south of Ben Nevis, which reach to heights of about 3000 feet. Another fact relied on, is the occurrence in Glen Nevis of rocks smoothed and striated, which it is thought may be best accounted for by heavy bodies of ice passing down the glen. Some importance also is attached to "a detrital bank at an altitude of 2904 feet," forming "for about 100 yards, and about 40 feet deep, a ridge or bank of loose material, broad enough for three persons to walk upon abreast, and containing much gravel and small rounded stones." In regard to this "detrital bank," Professor Heddle remarks:—"Whether *a glacier* showered down the heaps of stones which form the ridge, or whether it had been deposited by *aqueous agency*, may be matter of opinion" ("Report," p. 35).

The Convener feels difficulty in accepting this glacier theory as being sufficient of itself to explain all the phenomena.

Then, when it is said that on the summit of *Mullach nau Correan* (at a height of 3077 feet)—which "forms a great round dome of red granite"—"there are several small angular *blocks of pure white quartz rock*, the nearest locality of which is the peak of *Stob Bhan*," at a height of 3274 feet above the sea, I ask, where could a glacier have been formed, on which blocks could fall from *Stob Bhan*, to be carried to *Mullach nau Correan ?*

The *detrital bank*, "containing mud, gravel, and small rounded stones" at a height of 2904 feet, 100 yards long and 40 feet deep, seems more like a submarine bank than a moraine, especially as at that height, any glacier generated about *Stob Bhan* could have had no opportunity of collecting sufficient debris to form a moraine of such dimensions.

The *striations* on the rocks of Ben Nevis do not necessarily imply glacier action, for striations have often been seen in localities, as in islands, where no glacier could have existed.

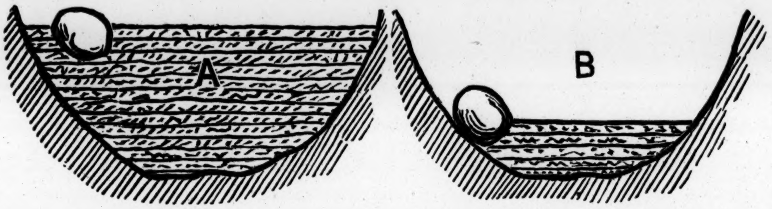
Professor Duns in his notes avoids adoption of any theory, but he mentions some facts which seem to suggest explanation. Thus, in noticing the "gravel heaps," he says, that the blocks which occur *in* them, are "subangular blocks of the immediate neighbourhood," and that the blocks which are *erratics*, occur *on* the gravel heaps; meaning apparently, that the gravel had been deposited first by one agency, and the erratics afterwards by another agency.

In referring to boulders occurring on "the mountain slopes," Professor Duns takes special notice of the remarkably precarious position of many large "granite boulders lying on mica schist rocks, where the side of the mountain slopes down so steeply as to make it a puzzle to understand, how they can remain in position" (pp. 23, 24).

It is also a puzzle to conceive what kind of agent it was which could set these boulders upon the steep slope of a hill so gently and exactly, as enabled the boulders to occupy positions of stability. One large porphyry boulder is mentioned with the "angle of its site to the horizon 35°" (page 23). Having been brought from a distance on a glacier or on floating ice, a boulder must in either case have fallen with such violence, as, by the reaction of concussion, to have slipped down any slope even though far from steep.

The only rational way, as it appears to me, of accounting for the position of these boulders is to suppose that the valleys became filled with detritus when the land was submerged, and that floating ice dropped boulders on the detritus. If the boulders were dropped near the side of a valley, the boulders, as the detritus was removed by rain and mountain streams, would slowly and gradually sink till they reached the slope of the hill, and would then find a resting place.

This view is indicated by the following diagram, where A represents a boulder in detritus, and B the same boulder when the detritus was nearly all removed from the valley:—



In the Seventh Report of the Committee I suggested this explanation of the position of two boulders lying on the steep side of a valley near Oban; and I now give these diagrams in further explanation of a difficulty which Professor Duns twice refers to in his notes.*

Another point brought out by Professor Duns is the arrangement of boulders in approximate *lines* or *rows*, of which several examples are given. He states that "they appear *in long lines*, some times far apart, but there is no mistaking their place in the lines which are W.N.W. and E.S.E." In another place he refers to "two *rows* of boulders being nearly direct west. The first block is grey granite, 7 × 4 × 6 feet, angle of site to horizon 40°, the others are grey granites, porphyries, and mica schists, their larger axis being N.N.W. and E.S.E."

Keeping in view the *trainées* of boulders mentioned by Dr. Heddle in last year's Report, as seen by him in Rannoch, it may be assumed that this arrangement of boulders is a feature requiring special attention, as probably indicative of the nature of the medium by which the boulders were brought to their present sites. I have no recollection of seeing in Switzerland, or hearing of boulders there, forming lines or rows after being projected from a glacier. But Arctic voyagers represent the sheets of ice formed along a rocky shore as often covered by blocks of stone which have rolled off the land, and which, when floated away from the shore, drop their cargoes. These possibly may form rows on the sea-bottom, if the ice raft followed a straight track, or if an iceberg ploughed its way among the boulders when on the sea-bottom, and pushed them aside into approximately straight lines.

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* That all or most of the valleys were filled originally with detritus is evident, from the account given in Dr. Heddle's notes of a great bank of detritus found by him at a height of 2904 feet (page 35); and from the fact mentioned by Professor Duns, that one very large gneiss boulder (weighing about 100 tons) was found by him on a steep slope at a height of 1500 feet, resting *mainly on three small rounded granite boulders* (page 24).

Professor Duns, whilst narrating the facts observed by him, has avoided theoretical speculation; but, after completing his record of facts, he concludes his notes by observing that "a careful examination of the deposits within the area described, so far as they bear on Arctic conditions of climate and a glacial surface, leads to the belief that the bulk of the phenomena may ultimately find their explanation in the recognition of two movements, one outwards from *Ben Nevis* as a centre, the other a force travelling from the W., the N.W., or the N.N.W." (page 23).

I presume from this remark that Professor Duns means that there have been two separate agencies, viz. (1) *glaciers* which filled the valleys and covered the mountain sides, and, after the land was submerged (2) *floating ice*, which came from the directions indicated by him.

If that view be correct, future observers in the Ben Nevis district, (and there is still an ample field there for further exploration), should endeavour to study what are the traces of each separate agency.

Whilst Dr. Heddle in his *Ben Nevis* excursions has seen mostly the traces of glacier action, he has elsewhere very clearly pointed out the evidence of a great and general movement over the country from a westerly direction. In the notes supplied for this Report he gives an example of blocks disrupted from a vein or dyke of white granite, in Glen Finnan, illustrated by a diagram (page. 32), carried up hill and for about one-third of a mile to the eastward; and he has also pointed out, as lying on the Ochil Hills, boulders of dolerite, red granite, and almond conglomerate, which he has identified with rocks *in situ*, some of them twenty miles distant, situated to the westward (page 31).

2. Another district which has been well surveyed is that near Inverness, and chiefly to the S. and S.E. A list of no less than about twenty large boulders in that district has been supplied by Mr. Wallace, master of the High School of that town;

In the case of those which he has been able to identify with rocks *in situ*, he states that they have all come from some westerly point. Mr. Richardson, a member of our Committee, has visited many of the boulders in the list given by Mr. Wallace, and states in his notes (page 11) that he was "struck with the number of boulders dotting eminences, and with the depth of sand which covered the hills, the whole pointing to a period of submergence in Post Pliocene times." In corroboration of this view, he cites the discovery last summer by Mr. James Fraser, C.E., Inverness, of Arctic marine shells at the height of 500 feet above the sea, at Drummore of Clava in this district."

3. Notes have also come to the Committee from Mr. Wm. Morrison, secretary to the Dingwall Field Naturalists' Club. He has traced the boulders of granite and mica schist which abound on Tulloch Hill, to rocks situated on Ben Wyvis and Cairn Cunnaig, hills situated from ten to twenty miles to the W. and N.W.

Nothing has, however, been discovered, to show decidedly whether the transporting agent was glacier or floating ice, except the physical outline of the country, which is quite unfavourable to the generation or movement of a glacier.

Mr. Morrison suggested for consideration a curious question—Whether certain *artificial cup-markings* discovered by him on one of the Tulloch Hill boulders might not have been cut before the date of some natural striæ which occur on the boulder? His reason for suggesting the question being that "these cup marks were faint, where the scorings are deepest and most frequent."

He drew my attention to the circumstance, stating that it was a question interesting alike to geologists and archæologists, so I wrote to ask specially whether any idea was entertained by him as to the possibility of the striæ on the boulder having been formed after the cup marks had been formed. His answer was:—"The suggestion formed on the mind unquestionably is, that the cups were partially obliterated by the scoring agent, and hence were made before the natural striæ" (page 16).

If this suggestion is supported by further examination and study, it would indeed be a very marvellous discovery, supporting the idea that glacial agencies had been in operation since the arrival of human inhabitants in Easter Ross.

But is it quite certain that the cup marks are, as Mr. Morrison thinks they are, *artificial* ?

Professor Duns, in his notes on Ben Nevis, mentions that on one of the boulders mentioned by him, "are several round hollows, so very like the cup-markings of the archæologist, that at first sight they seem artificial. But in another block, a bit having been noticed protruding from the surface on being struck with the hammer, fell out, leaving the cup-marking on the stone" (page 21).

Might not the cup-markings on the Tulloch boulder be of the same nature as those on the Ben Nevis boulder, which at first deceived Professor Duns?

4. Notices of some interest have been received regarding boulders in *North Ronaldshay*, Orkney, and from *Fair Isle* and *Lunna* in the Shetlands. Boulders on islands, which differ from the rocks of these islands, and can be identified with rocks of islands distant eight or ten miles, and separated by deep arms of the sea, are of extreme interest, because the theory of glaciers is quite inapplicable to them. Floating ice is the only possible solution, and if subject to the agency of tidal currents and varying winds, it will also explain why the directions of transport vary as they do in the Orkneys and Shetlands.

5. I have only now to allude to the small contribution which I have myself been able to supply for this year's Report. It is shown by a woodcut in the Report and by a coloured diagram on the wall. The boulders referred to in these, being a compact gneiss, whilst the rocks of the hill are clay slate, there can be no doubt that they are true erratics, and that they have come from the westward, as there are few gneiss rocks anywhere to the eastward, and they occur in abundance towards the west in Jura, Colonsay, Mull, and along the shores of Lochs Sweyn and Killesport.

The hill which bears these boulders, stands by itself, reaching to a height of 710 feet above sea-level. It is in a sort of amphitheatre formed by a range of hills both south and north, which reach to a height of from 1200 to 1500 feet, with openings towards both east and west. My conjecture, therefore, is that floating ice carrying boulders flowed in from the west, and, stranding on the hill, lodged there the boulders which now lie not only on the top, but on the south-east side of the hill.

There are several other facts mentioned in the Report, showing that through the gorge or kyle which lies between East and West Loch Tarbert a strong current must have passed, spreading boulders on each side of the gorge, striating rocks, and depositing detritus. The heaps of detritus are chiefly on the east, *i.e.*, the *lee* side of rocky knolls.

3. Supplement to the Eighth Report of the Boulder Committee.

Origin and Objects of the Committee appointed by the Royal Society of Edinburgh to obtain information regarding Boulders in Scotland.

The subject was brought before the Society by Mr. Milne Home in a paper referred to in the following Minute of Council, dated 21st April 1871 :—

"The Council, whilst authorising Mr. Milne Home's paper "On the Conservation of Remarkable Boulders in Scotland," to be read at an ordinary meeting of the Society, agree, in compliance with a suggestion in the paper, to express approval of its object, and of the scheme proposed for carrying it out.

"The Council nominate the following Fellows of the Society as a Committee to assist Mr. Milne Home in this matter.—Professor Christison, Professor Geikie, Professor Wyville Thomson, Rev. Thomas Brown, Captain White, R.E., Dr. Arthur Mitchell, Thomas Stevenson, C.E., Dr. Page, Professor Nicol (Aberdeen), Professor Young (Glasgow) ; Mr. Milne Home to be Convener. The Council agree to supply the Committee with copies of Mr. Milne Home's paper, when printed in the *Proceedings* of the Society, if the Committee should wish to circulate it, with a view to create an interest in carrying out the scheme."

(Signed) J. H. Balfour, *Secretary.*

The following extracts are made from Mr. Milne Home's paper, read on 5th May 1871.

Among many geological questions which wait solution, there is probably none more interesting or perplexing than the agency by which boulders or "blocs erratiques," as the French term them, have come to their present sites. I allude, not to blocks lying at the foot of some mountain crag from which they have fallen, but to blocks which have manifestly been transported great distances, after being detached from rocks of which they originally formed part.

That many of the large isolated blocks lying on our mountain sides and on our plains have come from a distance, and by some agency of tremendous power, is obvious even to an unscientific observer; and the perception of this truth by the popular mind has, in many cases, so invested these boulders with superstitious interest, that they have received names and suggested legends, which impute the transport of them to supernatural agents.

There are two circumstances which plainly indicate that these stones are strangers.

One is, that many of these blocks are in composition different from that of the rocks prevailing in or near the district where the blocks are situated, but similar to rocks in distant parts of the country.

The other is, that some blocks, whilst excessively hard,—so hard that it is difficult to break off a portion, are nevertheless round in form—a form evidently acquired by enormous friction—such friction as would result from being rolled or pushed a long way over a rough surface.

These round shaped blocks were the first to attract popular attention. The name given to them in Scotland of *boulders* has no doubt been suggested by their shape.

It is accordingly chiefly the rounded boulders which possess the traditionary names and legends by which many of them are known. Such names as *Carlin's Stane*, *Witch's Stane*, *Pech or Pict's Stone*, *Fingal's Putting Stone*, *Giant's Stone*, *Clach M'hor*, *Clachan-an-druid*, *Kirk-Stane*, *Pedlar's Stane*, *Thuggart Stane*, and *Devil's Putting Stane*, are all applicable to rounded blocks.

When the geologist turned *his* attention to the subject, it was soon discovered, that there were many blocks equally entitled to be called erratic, not round, but square shaped; and which, though discovered to belong probably to rocks at a great distance, yet showed signs of little or no attrition. Moreover, many of these angular or sharp-edged blocks were comparatively soft and loose in structure, so that they could not have been rolled or pushed for any considerable distance, without being broken or crushed.

On a minute inspection of erratic blocks, certain features were noticed which seemed to indicate the forces to which they had been subjected. Thus on many of them, deep scratches, ruts, and groovings were found, as if sharp pebbles or stones harder than themselves, had been squeezed against them under great pressure. It was also observed that, when a block had a long and a short axis, the longer axis was generally parallel with any well marked scratches or striæ on its surface; and, moreover, that the direction of these striæ frequently coincided with the direction of the parent rock.

These circumstances soon led geologists to speculate on the nature of the agencies which could have effected a transport.

After alluding to the different theories which had been suggested, to account for boulder transport, the paper proceeds as follows:—

It is not my intention to discuss these theories, or say which appears the most probable. I allude to them merely to indicate the tremendous character of the agencies, which it is found necessary to invoke for the solution of the problem,—agencies all implying a very different condition of things in Scotland, as regards configuration of surface and climate, from what now prevails. These phenomena are the more interesting, because, as most of the erratic blocks lie above all the rocks, and very frequently even above the beds of clay, gravel, and sand, which constitute the surface of the land we inhabit, they indicate probably the very last geological changes which occurred in this part of the earth's surface, and which there are some grounds for supposing, may even have occurred since this country was inhabited by man.

The basis on which geologists have been obliged to build their theories, it must be admitted, is sufficiently narrow. It consists merely of observations made casually by individuals, who have noticed certain appearances in districts which they happen to have visited; and, therefore, it is little to be wondered at, that more than half a century has been required for procuring the information, scanty as it is, which has been obtained.

What appears desirable for expediting the solution of the problem, is to discover and organise a staff of observers, for the purpose of discovering facts likely to throw light on the subject, and of making these facts known from time to time, both with a view to verification, and as a basis for further speculation.

It is probable that the numerous natural history societies and field clubs existing in Scotland, would be valuable agents in this investigation; and, moreover, that individual geologists might be induced to co-operate in their respective districts.

I hope no one will think that the object for which this investigation is now asked is not worthy of the trouble which it implies, and of the patronage which this Society is proposing to bestow on it. These erratic blocks bear the same relation to the history of our planet, as the ancient standing or memorial stones do to the history of the early races of man. These last-mentioned stones,—sometimes with sculpturing on them not yet understood,—sometimes arranged in circles or other regular forms not yet explained,—sometimes found in connection with sepulture, are beheld and studied with interest, or the gleams of light which they throw on the people who erected them; and popular indignation justly arises, when any of these prehistoric records are destroyed or mutilated. The great boulder stones to which I have been referring, would, if investigated and studied, in like manner cast light on the last tremendous agencies which have passed over whole regions of the earth. It is therefore important to have as many of these boulders as possible discovered and examined, and to have such of them preserved as seem worthy of study. I need not say how rapidly, during the last century, both classes of ancient stones have been disappearing; and therefore, if it be desirable to preserve the most remarkable boulders, the investigation which I advocate, cannot be too soon begun.

Alike in illustration and in recommendation of this suggestion, reference may be made to an investigation for the same object commenced two years ago in Switzerland, and in the adjoining parts of France. The design was twofold,—*First*, the conservation of remarkable boulders situated on the Jura and in Dauphiny; and *second*, the recording of their positions by maps, and of their characteristic features by schedules.

With this view a circular was drawn out, and issued by the Swiss Geological Commission, pointing out the scientific bearings of the subject, and invoking the co-operation not only of provincial societies, but also of municipal authorities, and of landed proprietors. A few extracts from the Swiss circular may not be inappropriate:—

"These erratic blocks are composed of granite, schist, or limestone;

but they rest on rocks of a different description. They are so remarkable by their number and size, that, from an early period, they attracted the attention of naturalists, and suggested scientific inquiries. It is, indeed, interesting to seek to comprehend how enormous masses, with from 40,000 to 50,000 cubic feet of contents, and weighing from 800 to 1000 tons, could be transported from the Alps from which they were evidently detached, to spots 40 and 50 leagues distant, crossing deep valleys, such as the lakes of Geneva, Neufchatel, Zurich, Constance, Lucerne, &c.

"This great problem has been discussed by numerous philosophers, both of Switzerland and of foreign countries." Then follows a list of names, including those of our own Playfair, Lyell, Murchison, Forbes, Tyndall, and Ramsay.

"Unhappily" (the circular goes on to state), "during the last 100 or 150 years, these erratics have been broken up for building purposes, and even for road metal. Recently the work of destruction has gone on more rapidly, and, unless stopped, the result will be to obliterate all traces of one of the greatest facts in the natural history of our country.

"Though the destruction of these blocks is now advancing with great rapidity, there are still a number of very large specimens left, and these the Geological Commission is anxious to preserve."

"The members of Archæological Societies are interested in the conservation of these blocks, for they often bear those curious sculpturings, to which much importance is now justly attached."

The appeal thus made to various societies and to municipal authorities in Switzerland, was most successful; as in many cases the proprietors on whose lands the boulders were found, in order to ensure their preservation, gave a right of property in them to different natural history societies.

Professor Favre of Geneva, who was the first to institute the movement in Switzerland, next addressed a letter to the Geological Society of France, with the same object. A Committee was appointed to report on the subject; and from their report, which was adopted by the Society, the following extract may be given:—"Such is the object pursued vigorously in Switzerland with the co-operation of departments and of individuals. In a word, see what is going on near ourselves. Can we remain outside of, and indifferent to, this scientific enterprise, especially when Mons. Favre has asked us to engage in the same work, and to undertake for our country what he is doing for his? We are bound to answer this appeal. The solution of the same questions ought to occupy us. These erratic phenomena abound everywhere in our district. The debris of rocks torn from the Alps cover the plain of Dauphiny, the plateau of the Dombes, the hills of Croix, Rousse, and Sainte-Foy. Already many geologists have studied these erratic phenomena in our neighbourhood, without being able to discover a solution. The truth, when we seek it, seems to fly from us, but we must persevere and pursue it till it is caught."

Professor Favre's efforts for the conservation and study of boulders were not confined to Switzerland and France. Having discovered that Scotland afforded an extensive field for inquiry, he sent to me a copy of the circulars which he had drawn out, and wrote several letters, from which the following passages may be quoted :—" Si vous pouvez organiser quelque chose de semblable en Ecosse, vous m'obligerez infiniment, en me tenant au courant."

In a subsequent letter, he says, " Permettez moi de vous renouveller la demande que je vous ai addressé, en vous priant de me tenir au courant de ce que vous ferez pour les blocs erratiques de l'Ecosse, et des resultats que vous obtiendrez."

I have given these details of the proceedings in Switzerland and France, and quoted these passages from Professor Favre's letters, in order both to add weight to my proposal, and show how we may proceed to attain it.

The disappearance of numerous camps, buildings, standing stones, and other objects of archæological interest in all our counties, which every one now regrets, has been owing in a great measure to ignorance on the part of the proprietors and tenants on whose lands they were situated, of the value and even nature of these objects. But this work of destruction has been happily stopped, and chiefly by the interference and influence of our Society of Antiquaries. In like manner, the demolition of boulders which has been going on rapidly in Scotland, will, I hope, be arrested, when the proprietors and tenants on whose land they stand, are made aware of the interest they excite, and of what is being done to preserve them in other countries. Of course, it would only be certain boulders which it would be desirable to preserve, boulders remarkable for size, or shape, or position, or for markings upon them; and when a report was made to the Committee of any boulder of this description, the Committee would judge whether an application should be made to the proprietor on whose lands it was situated, to spare the stone, so that it might be preserved for examination and study. I have little doubt that such an appeal would be attended to. Indeed, in the great majority of cases, a proprietor would be pleased to learn, that an object of scientific interest had been discovered on his estate, and would be glad to have it in his power to accede to any request in relation to it coming from a Committee of this Society.

The first step taken by the Committee was to send out about 700 circulars to parochial ministers in Scotch counties, containing queries, with the view—

1. Of ascertaining localities where boulders exceeding 50 tons in weight existed.
2. Of obtaining the dimensions of these boulders.
3. Of learning whether the rocks beneath and near these boulders, were the same as or different from the rock composing the boulders.
4. Of inquiring whether there existed any accumulations of sand or gravel in the form of mounds, or elongated embankments, above sea level.
5. Of ascertaining whether these boulders were known by any traditional name or legend.

These 700 circulars produced about 100 answers, containing much valuable information. But the Committee on considering the answers came to be of opinion, that they had acted injudiciously in asking information only regarding boulders exceeding 50 tons in weight.

They thereupon resolved to send out another circular containing the same queries as before, but extending to boulders of 20 tons and upwards in weight.

The Committee fearing that they might be considered troublesome, in again applying to ministers of parishes, addressed their second circular to parochial schoolmasters.

The answers received from them contained a very large amount of information.

The answers to both circulars were then carefully examined by different members of Committee; and it was resolved to classify the information according to counties. The first report of the Committee was laid before a meeting of the Royal Society in April 1872. It gives in a condensed form, for counties (alphabetically arranged) and for parishes in each county, a list of boulders with particulars regarding the nature of the rock composing them, and other features of geological interest.

The first report also contains information of archæological of traditional interest regarding some of the boulders. But in the reports of subsequent years, the information given is almost exclusively geological.

They include also occasional references to beds of gravel and sand, existing whether as mounds or in elongated embankments;—and with the view of considering whether they might be considered to be ancient moraines, and therefore indicative of local glaciers, or to be submarine banks, and in this last case, indicative of a submergence of the land.

The chief object of the Committee has been to collect facts, and not to announce conclusions. But it was also important to obtain data, bearing on the different theories of boulder transport. Thus in many cases the positions of boulders have been specially noted when these indicated the direction from which they probably came. In some cases their heights along the sea were specially noted when above the level of any possible glacier; or their positions on islands, where the existence of glaciers was most unlikely. So also, the smooth and rough sides of rocks, were studied and explained when they showed from what quarter the smoothing agent seemed to have passed over the rocks.

The Committee have now completed seven reports. These were laid before meetings of the Royal Society, and have been published in the Society's *Proceedings*. An eighth report is now in progress.

But a wish has been frequently expressed to have an index or an abstract of the information contained in all the reports. His Grace the Duke of Argyle, in his paper " On the Geology of the Highlands," read at the last Glasgow meeting of the British Association, whilst referring to the valuable information contained in the reports then published, expressed a hope that an abstract should be drawn out by the Committee. The late Sir Robert Christison at almost every meeting reiterated the same wish.

The Convener of the Committee has made an attempt to carry out these suggestions, by gathering out of the seven reports already published, all the facts, applicable to the respective counties, in alphabetical order.

The compendium is such that any one wishing to learn something of the boulders in any particular county, or parish of that county (in so far as reported to the Committee), will be at once able to get that information.

But besides a topographical abstract merely to show where boulders of all kinds occur, one of perhaps greater interest might be formed, classifying boulders, under such heads as the following, and indicating the reports where they are noticed :—(1) Boulders of great size or weight :—(2) boulders perched on peaks or summits of hills ; (3) boulders at very high levels above the sea ; (4) boulders on islands remote from any mainland ; (5) boulder transport in so far as indicated by the ascertained direction of parent rock, or by the bearing of longer axis of boulders, or by the direction and depth of striæ on their surfaces.

Another heading in such an abstract, might be a reference to localities where great accumulations of sand and gravel occur, whether in the form of mounds, or embankments, or of horizontal terraces, and at various heights above the sea; for notices of these occur in several of the reports.